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ERRATA

Page 2, footnote, line 1, "augustis" should read "angustis."
Page 2, footnote, line 2, "ate" should read "late."

Page 28, line 30, "Taenia ovis (Cobbold, 1869) Ransom, n. comb., 1913," should read "Taenia ovis (Cobbold, 1869), Ransom, 1913."

Page 98, line 5, "Figs. 3 and 7.—Side and dorsal views of female" should read "Figs. 3 and 7.—Side and dorsal views of male. Figs. 4 and 8.—Side and dorsal views of female."

Page 176, line 19, "Prunus havardii W. F. Wight, n. comb." should read "Prunus havardii (W. F. Wight), n. comb."

Page 421, footnote, line 2, "locularis" should read "locularibus."
Page 421, footnote, line 7, "locularis" should read "loculare."

Page 425, figure 4, "gabonensis" should read "gabunensis."

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FOREWORD

The recent advances in the theory and practice of agriculture have come almost entirely from scientific research applied to agricultural problems. Accumulated results of centuries of painstaking studies have been drawn upon, and it has become evident that further improvement in agriculture calls for continued investigation of the most accurate and thorough nature. The first recognition of the economic value of progress in these investigations as well as the initial application of theories to practical problems comes usually from specialists. Indeed, only in rare instances is the significance of the results of scientific research apparent to farmers, since newly discovered facts are seldom directly applicable to agricultural conditions.

The suggestive or the indirect value of reports of new work is usually of paramount economic importance; it is the purpose of the Journal of Agricultural Research, therefore, to record investigations bearing directly or indirectly upon economic conditions of agriculture. It is hoped that permanence of record of new data may be secured by sending the Journal in its entirety to special libraries and institutions which make suitable exchanges and that a liberal distribution of the reprinted papers to interested specialists may enhance the usefulness of the separate articles.

The first few issues will contain papers from the Department of Agriculture only. Plans, however, are now being perfected in accordance with the tentative suggestions made to the Secretary of Agriculture by the executive committee of the Association of American Agricultural Colleges and Experiment Stations so that articles prepared and submitted by investigators in the State agricultural colleges and experiment stations will eventually be included in the Journal.

B. T. GALLOWAY,
Assistant Secretary of Agriculture.

Washington, D. C.,
October 1, 1913.

JOURNAL OF AGRICULTURAL RESEARCH
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CITRUS ICHANGENSIS, A PROMISING, HARDY, NEW SPECIES FROM SOUTHWESTERN CHINA AND ASSAM

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INTRODUCTION

A study of the wild relatives of the orange begun a few years ago in the hope of finding new material for use in hybridization or as stocks has resulted in bringing to light a number of very interesting wild species, some of them new and many of them very little known. One of the most remarkable of these is a wild Citrus, native to southwestern China. This species is cultivated in the vicinity of Ichang, and it bears a very large lemonlike fruit that is of sufficiently good quality to cause it to be shipped to markets several hundred miles distant. It grows wild farther to the north and at a higher altitude than any other species of Citrus and is undoubtedly very hardy, which makes it of great promise for use in breeding cold-resistant citrous fruits. Because of its unusually large seeds it promises to yield very vigorous seedlings and to be, in consequence, a useful stock on which to graft oranges, lemons, and other cultivated species of the genus.

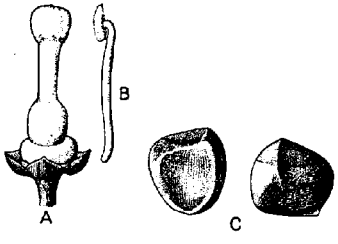

FIG. 1.—*Citrus ichangensis*, n. sp.: *A*, Pistil after the petals and 3 tamens have dropped but before the style has fallen off; from a paratype in the herbarium of the Arnold Arboretum; E. H. Wilson No. 2230A; 2½ times natural size. *B*, Stamen as seen from one side; from a paratype in the herbarium of the Arnold Arboretum; E. H. Wilson No. 2230A; 2½ times natural size. *C*, Two seeds deformed by mutual pressure; from a paratype in the National Herbarium; A. Henry No. 3423 (?), bottle A; natural size. (Drawn by J. M. Shull.)

Mr. Augustine Henry collected excellent material of this species around Ichang, China, from 1885 to 1888. His specimens are found in many herbaria under the name "*Citrus medica* L., var." The best specimens, however, are those collected by Mr. E. H. Wilson, first in 1900 to 1903 for Veitch & Sons, and again in 1907 for the Arnold Arboretum, this latter material comprising an abundance of flowering specimens, young fruits, and also ripe fruits in alcohol.

The director of the Arnold Arboretum, Prof. C. S. Sargent, has very kindly turned over to the writer all this valuable material. Thanks are also due to Mr. E. H. Wilson for furnishing very full notes about his specimens and for his observations on the use of this species as a substitute for the lemon.

In China this species occurs in an undoubted wild state in the hills of the Upper Yangtze Valley from Ichang west and southwest in Hupeh, Szechwan, and Kweichow, growing at altitudes of 1,500 to 6,000 feet. In Assam a closely related but slightly different form is found at an altitude of 5,000 to 6,000 feet in the Khasi Hills. Doubtless other similar forms occur to the eastward in that province and in Upper Burma as well. The species thus ranges over a region at least 1,500 miles long and some 500 miles wide.

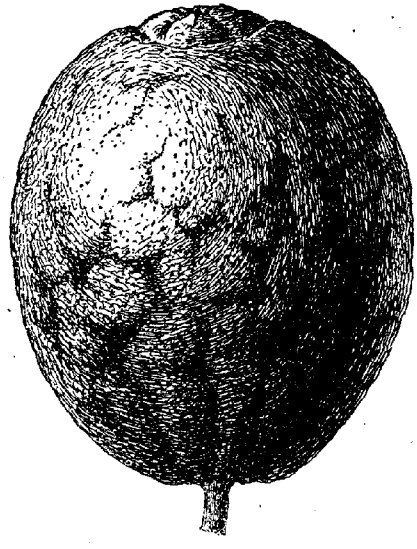

FIG. 2.—*Citrus ichangensis*, n. sp.: Fruit showing the very low, broad, apical papilla circumscribed by a shallow furrow; from a paratype in the National Herbarium; E. H. Wilson No. 4736; natural size. (Drawn by J. M. Shull.)

This plant is reported in all parts of its range as growing in a truly wild state and is cultivated on a small scale around Ichang along the Yangtze River, where the fruit is called the "Ichang lemon" by foreigners.

TECHNICAL DESCRIPTION OF CITRUS ICHANGENSIS

Citrus ichangensis is strikingly unlike any other Citrus native to China and is easily distinguished from all its congeners. Its technical description is as follows:[1]

[1] **Citrus ichangensis,** sp. nov.—Citrus foliis augustis, latitudine 4 plo vel 6 plo longioribus, petiolis atealatis, obovatis vel oblongis ad basin abrupteattenuatis, laminis ovato-acuminatis, vix petiolis aequantibus, floribus grandibus, 5-meris, staminibus 20, connatis, polyadelphiis, seminibus numerosis, grandibus.

Frutex vel arbor 1–10 metralis (plerumque 1–5 met.); rami juniores angulati saepe spinosisimi, 2–4 mm. diameter. Folia angusta, 60–135×15–33 mm. (plerumque 80×115–10–30 mm.), petiolis late alatis, laminis saepe aequantibus vel superantibus, obovatis ellipticis vel oblongo-spathulatis ad basin abrupte attenuatis, apice regulariter rotundatis vel truncatis vel subcordatis; laminis ovato-acuminatis plus minusve caudatis apice leviter emarginatis, ad basin regulariter rotundatis vel obtuso-cuneatis. Flores grandes, 20–35 mm. diam., 5-meri, solitarii, axillarii; pedicellis 3–5 mm. longis, calycibus sepalis crassis subtriangularibus, 3×3 mm., margine minute ciliatis; petalis oblongis 15–20×5–8 mm., staminibus 20, connatis, usque ad apicem cohaerentibus, polyadelphiis in fasciculis 3–5, 8–10 mm. longis, stylis 3–4×1¼ mm., caducis; stigmatibus 2–2½ mm. longis, 3 mm. latis ovariis paullo minoribus, ovariis 3×3 mm., 8–11-locularibus. Fructus grandis, 7–10 cm. ×9–10 cm., ovalis, ad basin tuberculato-sulcatus, apice cum papilla magna vix prominenti, sulco circulari plus minusve 25 mm. diam. circumdata, cortice crasso 7–9 mm. diam.; segmentis 8–11, pulpa vesiculari acida, seminibus grandibus 15–20×10–14×7–11 mm. ovato-acutis, polyembryonicis, 40–70 in fructu singulo.

Citrus ichangensis Swingle.

A spiny shrub or small tree usually 5 to 15 feet high. Leaves narrow, 4 to 6 times longer than wide, mostly 80 to 115 by 18 to 30 mm., with very large broadly winged obovate or oblong spatulate petioles evenly rounded at the tip and narrowed abruptly at the base, usually 35 to 60 by 20 to 30 mm.; with ovate-acuminate laminæ more or less caudate, emarginate at the tip and evenly rounded or bluntly pointed at the base, usually 30 to 60 by 18 to 30 mm., often not equaling the winged petiole in area. Flowers about 25 mm. in diameter; 5-merous; stamens 20, at first all connate to the tips, finally breaking up into several bundles, about 10 mm. long. Pistil about 10 mm.

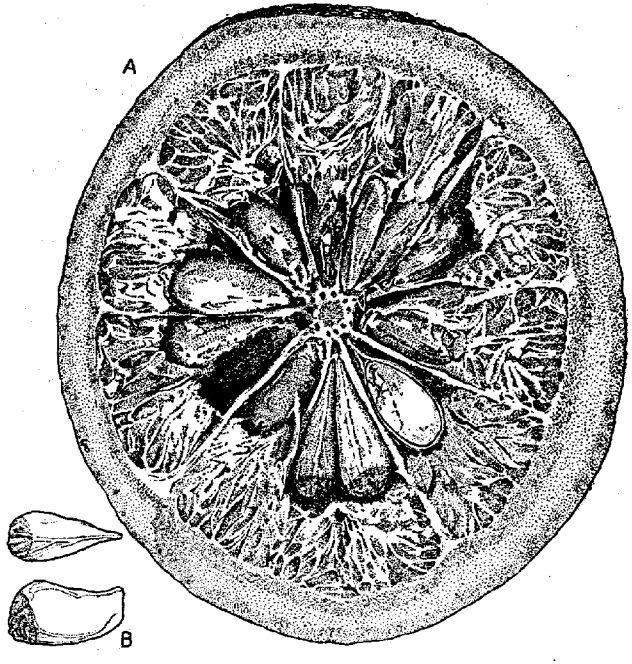

FIG. 3.—*Citrus ichangensis*, n. sp., from paratypes in the National Herbarium: E. H. Wilson No. 4737: *A*, Cross section of a large fruit; natural size. *B*, seeds; natural size. (Drawn by J. F. Brewer.)

long; stigma nearly as large as the ovary; style short, caducous; ovary 8 to 11 celled; ovules numerous in each cell. Fruit large, slightly oval, 8 to 11 by 7 to 10 cm., with a rough and furrowed base and a broad very low papilla at the tip, about 25 mm. in diameter, circumscribed by a shallow furrow; peel rather rough, 6 to 10 mm. thick. Segments 8 to 11, nearly half filled with seeds; pulp vesicles fusiform, 8 to 12 by 2 to 4 mm. on stalks 2 to 8 mm. long. Seeds very large, usually 16 to 18 by 11 to 12 by 7 to 10 mm., more or less angular from mutual pressure, 40 to 70 per fruit, polyembryonic; cotyledons thick and fleshy. (See Pl. I and figs 1 to 7.)

This species differs from its congeners in having very large thick seeds and slender leaves four to six times longer than broad, with very large, winged petioles often as large or larger than the blade. It differs from *Citrus histrix* DC. in having oblong rather than triangular winged petioles and much larger flowers with connate stamens.

DISTRIBUTION: CENTRAL AND SOUTHWESTERN CHINA. 1. HUPEH PROVINCE[1]

ICH'ANG PREFECTURE.—Vicinity of **Ich'ang.** A. HENRY, No. 3423, 1887 (?), "Thorny bush 4 ft., white flowers; in a wild jungly place; a wild plant." Flowers, Kew, Paris (Muséum), Dahlem, Harvard (Gray Herbarium), Washington, D. C. (National Herbarium); **A.** HENRY, "Bottle A," "fruit from same shrub as 3423," 1887 (?); twigs and fruits, Kew; seeds (fig. 1, *C*), Washington, D. C. (National Herbarium). **Pingshan Pa** (in Ich'ang George, 10 km. [6¼ miles] northwest of Ich'ang), E. H. WILSON, No. 4736 (small fruit, see fig. 2), No. 4737 (large fruit, fig. 3), November, 1907, fruits only (in spirits) from cultivated trees. Harvard (Arnold Arboretum), Washington, D. C. (National Herbarium). **Ch'angyang** (25 km. [15½ miles] south-southwest of Ich'ang), A. HENRY, No. 7695, no date. "Shrub 6 to 7 ft.," fruits, Kew, sterile twigs, Harvard (Gray Herbarium); **Nanto** (20 km. [12½ miles] northwest of Ich'ang), E. H. WILSON, No. 202, April 25, 1900, flowers, Kew, Dahlem, Harvard (Arnold Arboretum), New York (Botanical Garden). **San-Yu-Tung Glen,** 10 li [4 miles] from entrance (13 km. [8¼ miles] northwest of Ich'ang), E. H. WILSON, No. 2230B, July, 1907, "bushy tree, 15 ft., cultivated." Fruits (see fig. 4, *B*), Harvard (Arnold Arboretum). Also eight duplicate specimens for distribution. **Hsingshan District** (about 17 km. [10½ miles] southeast of Hsingshan), 10 li (5.8 km. or 4 miles) below "Liang-Shan-Kou" (altitude 1,500 to 2,000 ft.), E. H. WILSON, No. 2230, May 7, 1907,[2] "bush, 3 to 5 ft., flowers white, ravine," flowers, Harvard (Arnold Arboretum) 2 sheets.[3] (Also 8 duplicate specimens for distribution.) **Hsingshan District,** about 14 km. north-northwest of Hsingshan, 8 li (4½ km. or 3⅛ miles) beyond "Li-Er-Kou" (altitude 4,200 ft.), E. H. WILSON, No. 2230A, May 15, 1907, "Citrus, bush or tree, 3 to 20 ft., flowers white, escaped from cultivation, roadside," flowers (see figs. 1, *A* and *B*, and 4, *C*), Harvard (Arnold Arboretum). Five duplicate specimens for distribution.

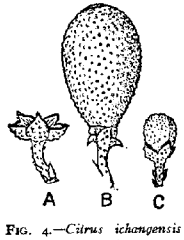

FIG. 4.—*Citrus ichangensis* from paratypes in the herbarium of the Arnold Arboretum: *A*, Calyx of dwarf wild form and pedicel with bracts, E. H. Wilson No. 3307, natural size; *B*, young fruit, E. H. Wilson No. 2230B, natural size; *C*, flower bud and pedicel with bracts, E. H. Wilson No. 2230A, natural size. (Drawn by Theo. Holm.)

[1] The geographic names in China are in southern Mandarin in accordance with the spelling given in L. Richard's, 1908, Comprehensive Geography of the Chinese Empire . . . Revised and translated into English by M. Kennelly. Shanghai, p. 558–639.

[2] Mr. Wilson's diary for this date reads as follows: "In ravine gathered specimens of a wild citrus from bushes 3 to 5 ft. tall, growing on cliffs of hard limestone." Photographs of this ravine taken by Mr. Wilson have been distributed as Nos. 025 and 032.

[3] One twig with flowers on one of the sheets is the type (see Pl. I and fig. 5). The other specimens of this same number resemble the type very closely, and some of them very probably were cut from the same plant, in which case they would be merotypes.

II. SZECHW'AN PROVINCE.

KW'EICHOW PREFECTURE.—Near **Wu Shan** (35 km. [22 miles] east of Kw'eichow), A. HENRY, No. 7130, no date, fruits, Kew, British Museum, Harvard (Gray Herbarium); **Kw'eichow Gorges: Fang Hsiang Hsia** (Wind Box Gorge), E. H. WILSON, No. 3307, May 1903, "2 to 3 ft., spontaneous,"[1] flowers (see figs. 4, *A*, and 6) Kew, Harvard (Arnold Arboretum).

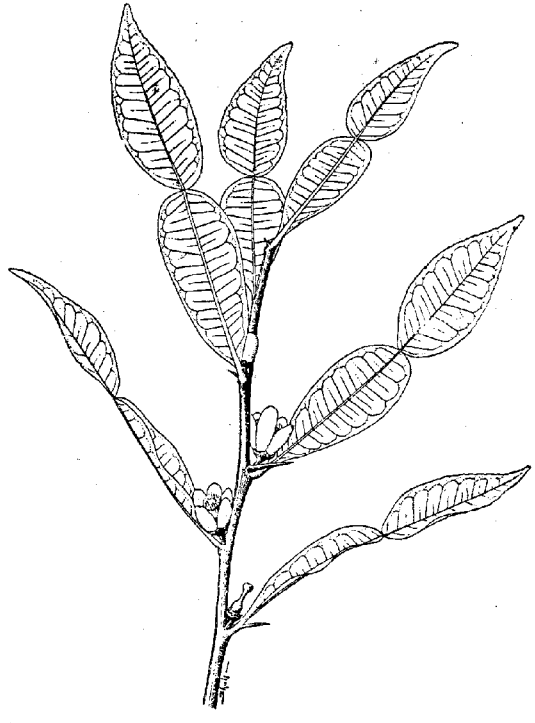

FIG. 5.—*Citrus ichangensis*: Flowering branch from the type specimen; E. H. Wilson, No. 2230; ½ natural size. (Drawn by J. M. Shull.)

CH'UNG K'ING PREFECTURE.—**Nanchw'an District** (about 75 km. [47 miles] southeast of Ch'ungk'ing), "Hou Ts'ao Kou,"[2] A. v. ROSTHORN, No. 175, July, 1891, "in dense woods," sterile twigs, Dahlem; "Huang Ai Shan,"[2] A. v. ROSTHORN, No. 1264, sterile twigs, Dahlem.

SUITING PREFECTURE.—**Ch'engk'ow t'ing** (about 135 km. [84 miles] northeast of Suiting), R. P. FARGES, no date, flowers, Paris (Muséum).

[1] Wilson, E. H., 1905, referring to this plant and locality, says: "Citrus japonica, 'Kumquat,' was common on the cliffs and evidently spontaneous." Gard. Chron., s. 3, v. 38, no. 969, p. 65, July 22, 1905.

[2] Cf. Diels, L., Die Flora von Central-China, 1900, Bot. Jahrb. [Engler], Bd. 29, Heft. 3/4, p. 424-425, Dec. 4, 1900.

III. KWEICHOW PROVINCE.

KWEIYANG PREFECTURE.—**K'ai Chow** (?) (60 km. [37 miles] north-northeast of Kweiyang. Altitude 5,577 ft.), M. CAVALERIE, no date, young fruit, Paris (Muséum).[1]

DETAILED DESCRIPTION OF CITRUS ICHANGENSIS

The typical *Citrus ichangensis* as it occurs in southwestern China is a small tree or a large shrub, usually 5 to 15 feet high (1.5 to 5 meters), but sometimes reaching 20 feet. It also occurs wild in fruiting condition only 2 to 3 feet high on the cliffs of the Yangtze Gorges.

FIG. 6.—*Citrus ichangensis*: Flowering branch of dwarf wild form; E. H. Wilson No. 2230A; natural size. (Drawn by Theo. Holm.)

The twigs of the current growth are 2 to 4 mm. in diameter and conspicuously angled, as is common in Citrus. The spines are straight, usually 1 to 2 cm., sometimes 2 to 3 cm. long, and 2 to 3 mm. in diameter at the base; they occur singly at one side of the axillary buds. (Pl. I and figs. 6 and 7.) Some specimens have very small spines or none at all. A few nodes at the base of the twig are often spineless.

The leaves are long and slender and remarkable because of the size of the winged petiole, which is sometimes larger than the blade. The leaves

[1] All of the specimens in this list have been studied by the writer and most of them have been photographed, so all are to be considered as truly paratypic.

are from 60 to 135 mm., generally 80 to 115 mm. long, and from 12 to 32 mm., mostly 18 to 30 mm. wide, the length being usually four or five

FIG. 7.—*Citrus ichangensis:* Flowering branch from a paratype in the herbarium of the Arnold Arboretum; E. H. Wilson No. 2230A; natural size. (Drawn by Theo. Holm.)

times the width. The winged petioles are obovate or spatulate oblong, rather abruptly narrowed into a wingless but sometimes margined base,

evenly rounded at the tip or sometimes truncate or subcordate, 25 to 72 by 12 to 33 mm., usually 35 to 60 by 20 to 30 mm., the wingless basal portion being 4 to 5 mm. long and 1½ to 2 mm. in diameter. The blades are ovate acuminate or elliptical acuminate, evenly rounded or very bluntly pointed at the base and narrowed into a more or less acuminate or caudate apex, which is, however, abruptly rounded and usually emarginate at the very tip, 20 to 66 by 13 to 30 mm., usually 30 to 60 by 18 to 30 mm. (See Pl. I and figs. 6 and 7.) The petioles and laminæ have rather numerous slender secondary veins that run nearly parallel and rather straight almost to the margin, making an angle with the midrib varying from about 45° to nearly 90°. (See fig. 5.) The internodes are 12 to 30 mm., usually 15 to 20 mm., long.

The flowers are borne singly in the axils of the leaves (alongside of the spine when present); they seldom occur at the end of the twigs. The flower buds are cylindric or subcylindric, with a hemispherical tip and a truncate base, all parts being very prominently glandular dotted. (See figs. 4, 6, and 7.) The pedicels are short and slender, 4 to 6 mm. long, 1 to 2 mm. in diameter, prominently glandular dotted, with a few very small bracts near the base. The calyx is fleshy, 4 to 6 mm. in diameter; the sepals are subtriangular, 3 by 3 mm., thick and fleshy, margins minutely ciliate. The corolla is white; when fully open it is about 25 to 30 mm. in diameter, with cylindric-oval petals 12 to 18 mm. by 8 to 10 mm. wide, and 20 stamens 8 to 10 mm. long cohering almost the whole length but separating into a few bundles in fully developed flowers. The anthers are 2 to 3 by 1 to 1½ mm. in size. The pistil is about 10 mm. long, stout, on a cushionlike disk 2½ mm. high and 4 mm. in diameter, with a subglobose ovary 4 by 4 mm. The style is stout, 4 mm. long, 1 to 1½ mm. in diameter, caducous, leaving a very short basal portion attached to the fruit. The stigma is large, subglobose, 2 to 3 mm. in diameter, almost as large as the ovary, which is 8 to 11 celled, with numerous ovules in each cell. (See fig. 1, *A*.)

The fruits are subglobose, slightly longer than wide, 8 to 11 cm. (3⅛ to 4¼ inches) long, 7 to 10 cm. (2¾ to 4 inches) in diameter, with a wrinkled and furrowed base and an inconspicuous, very low, and broad papilla at the top, tipped with the persistent base of the style and delimited by a shallow circular furrow, making a circle about 20 to 35 mm. in diameter, usually 25 to 30 mm. (See fig. 2.) The fruits look like very large, short and thick lemons.

The peel is rather rough, resembling that of a large lemon, 6 to 10 mm. thick, usually 7 to 9 mm. There are from 8 to 11 segments. In a large 11-celled fruit (Wilson No. 4737) the segments are 72 mm. long, 25 to 35 mm. wide, and 20 mm. thick; in a small 8-celled fruit (Wilson No. 4736) from the same locality they are 60 mm. long, 25 mm. wide, and 18 to 22 mm. thick.

The pulp vesicles are fusiform, pointed at both ends, 8 to 12 by 2 to 4 mm., rarely reaching 18 mm. in length, on a slender stalk 2 to 8 or rarely 10 mm. long, attached to the dorsal ovary wall and also along the peripheral half of the membrane dividing the segments. The core is solid, 6 to 10 mm. in diameter, more or less stellate in cross section because of the thickening of the membranes at their attachment. The center of the core is less solid than the periphery, where there are small groups of fibrovascular bundles opposite the attachment of each membrane.

The seeds are very large, light brown in alcoholic material, very numerous, from 40 to 70 in a single fruit and from 4 to 10 in a segment. Usually from 4 to 6 large seeds and sometimes one or more small ones occur in a segment. The seeds are cuneate ovate in outline seen from above and oval or subquadrangular seen from the side, 15 to 20 mm. long, 10 to 14 mm. wide, 7 to 11 mm. thick, mostly 16 to 18 by 11 to 12 by 7 to 10 mm., with a straight edge 6 to 8 mm. long where attached to the placenta. (See fig. 3, *A* and *B*.) They have a dark-brown cap 8 to 10 mm. in diameter at the base; the outer seed coat is thick, tough, and cartaceous, while the inner coat is thin and silky. The seeds of the wild form, collected in the vicinity of Ichang by Henry (No. 3423), are more angular through mutual pressure than those of the cultivated specimen and are also thicker. (See fig. 1, *C*.)

There are often two large embryos and usually several small ones in a single seed. Frequently the cotyledons are greatly deformed by mutual pressure of the several embryos. It is almost certain from the structure of the seeds of *Citrus ichangensis* that the cotyledons remain buried in the soil during germination, as in all the commonly cultivated species of the genus.

The dwarfed wild form of the species, found near the eastern end of the Windbox Gorge just below Kweichow (Wilson No. 3307), grows only 2 to 3 feet high and bears diminutive leaves scarcely over one-third the size of those of the cultivated form, the petioles being 16 to 23 by 7 to 8 mm. and the blades 7 to 15 by 4 to 7 mm. in size. In striking contrast to the diminutive leaves are the very numerous long spines which are unusual in showing a slight upward curvature. (See fig. 3.) Doubtless the habitat of this form on semiarid cliffs will serve to explain its small size.

Fruits collected by Augustine Henry near Ichang, likewise from a wild form, are remarkable for the fact that the numerous short, thick, and very large seeds occupy all the space in the segments, leaving room for scarcely any juice. The seeds are rather narrower in the cultivated form, but possibly this is in part due to their having an abundance of space in which to develop.

Still, in all essential characters the cultivated and wild forms agree, and doubtless the larger, juicier fruit of the cultivated form is due in part to the better nourishment the tree receives and also in part to the selection

practiced by the Chinese gardeners, who would naturally have chosen the most promising of the wild forms to propagate. Unlike many other cultivated citrous fruits, this species shows no evidence of having been hybridized; it is rather a selected form of a wild species.

Both the wild and cultivated forms of *Citrus ichangensis* will be secured as soon as possible for trial in this country. Careful exploration at higher altitudes near the northern limit of the species in China should bring to light exceptionally hardy forms that would be invaluable to breeders of hardy citrous fruits.

THE RELATIONSHIPS OF CITRUS ICHANGENSIS

Citrus ichangensis stands apart from all the other known members of the genus. Its huge, thick seeds are unlike anything heretofore known in Citrus, and its long, slender leaves with their very large, broadly winged petioles, often exceeding the blade in area, distinguish it at once from most of its congeners.

Citrus histrix DC., a curious and little-known East Indian species, also has leaves with broadly winged petioles, often larger than the blades, but differs greatly from *Citrus ichangensis* in having very small flowers, often only 4-parted, with perfectly free stamens. Even the broadly winged petioles of *C. histrix* are distinctly different, being more gradually narrowed toward the base and usually more abruptly truncate at the tip, making them somewhat triangular in outline, whereas those of the Chinese species are often oblong or elongate elliptical.

The other species of Citrus having very large, broadly winged petioles, such as *C. celebica* Koord., *C. papuana* Bail., and *C. macroptera* Montr., native to the Malayo-Polynesian region, are apparently closely related to *C. histrix*, if, indeed, they are not to be considered as forms of it. They all agree with *C. histrix* in having winged petioles more or less triangular in outline and show no close affinity with *Citrus ichangensis*.

The bulky seeds of *Citrus ichangensis* with their large brown caps and thick deformed cotyledons are so much larger than those of its congeners they can not be mistaken for those of any other species of Citrus. They are much more like those of the African species of hard-shelled citrous fruits belonging to the genera Balsamocitrus and Aeglopsis.[1]

PREVIOUSLY PUBLISHED NOTICES OF THE SPECIES

In 1907 L. Diels[2] referred to *Citrus histrix* DC., two numbers collected by A. v. Rosthorn in Szechwan in 1891, noting that one (No. 1264) had narrower leaves with inconspicuous venation and the other (No. 175)

[1] Stapf, Otto, 1906. Plantae novae Daweanae in Uganda lectae. Jour. Linn. Soc. [London] Bot., v. 37, p. 505, pl. 22.

Swingle, Walter T., 1912. Le genre Balsamocitrus et un nouveau genre voisin, Æglopsis. Soc. Bot. France, t. 58 s. 4, t. 11), (Mém. 8d.) p. 236 and 241, fig. B and pl. 3.

[2] Diels, L., 1900. Die Flora von Central-China. Bot. Jahrb. [Engler], Bd. 29, Heft. 3/4, p. 424.

broader, distinctly veined leaves. Sterile specimens of both of these numbers in the herbarium at Dahlem belong undoubtedly to *Citrus ichangensis* and differ but slightly in shape and venation.

In 1911 H. Léveillé published a "*Citrus Cavaleriei*" in an article by Julien Cavalerie[1] without a recognizable description. A specimen collected by Père Julien Cavalerie in the Province of Kweichow, China, preserved in the Muséum d'Histoire Naturelle at Paris, is almost certainly *Citrus ichangensis*. In his account of the Aurantiaceæ of Kweichow, he says of this species:

> *Citrus Cavaleriei*, Lévl. I found in the forest, remote from any habitation in the vicinity of Ma-Jo and of Kai-Tchéou [K'ai Chow] at about 1,700 meters [5,577 feet] altitude, a kind of spiny orange tree, in the undergrowth of the forested slopes. The tree is arched (voûté) and completely covered with moss. One tree had fruits of the size of an apricot and flowers at the same time. The fruit is hard and rounded in shape; the winged petiole is so much developed that it constitutes half of the leaf. I did not see this tree cultivated anywhere. It is the only wild species [of Citrus] in the high regions.[2]

There is nothing in this description to distinguish this plant from *Citrus histrix* DC., and upon applying to M. Léveillé to see the type specimen he declared this name to be "a true *nomen nudum*" that had been published by mistake, and a note to this effect was later published.[3]

A SUBSPECIES FROM THE KHASI HILLS

Several good specimens of a Citrus from the Khasi Hills in Assam, collected by J. D. Hooker and T. Thomson in 1850 and preserved in the Kew Herbarium, were at first supposed by the writer to be identical with *Citrus ichangensis*, as they showed the same peculiar, very large and broadly oval or oblong winged petioles. After careful study, however, the Khasi specimens were found to differ from the typical Chinese material in a number of points.

In the first place, all of the Khasi specimens show leaves with less acuminate blades than those of the Chinese material; moreover, the leaves of the Indian specimens are distinctly more variable both in size and in shape. The immature fruits collected by Hooker and Thomson in this locality are all slightly oblate instead of slightly prolate like the Chinese fruits from Pingshan Pa (Wilson Nos. 4736, 4737). The fact that Hooker and Thomson call this plant a "wild orange" is additional evidence that the fruits did not have the lemonlike appearance of the Chinese form. Finally, the flowers in Clarke's specimen preserved in the British Museum occur in three to six flowered axillary panicles instead of singly, as in all the Chinese material seen. The tree reaches a height of

[1] Cavalerie, Julien, 1911. Les Aurantiacées du Kouy-Tchéou. Bul. de Géogr. Bot., t. 21 (ann. 20, s. 4), no. 261, p. 211.

[2] Translation from Cavalerie, Julien, 1911, loc. cit.

[3] L[éveillé], H., 1911. Les Aurantiacées du Kouy-Tchéou. Bul. de Géogr. Bot., t. 21 (ann. 20, s. 4), no. 262, p. 236.

30 feet in the Khasi region and has not been recorded over 20 feet in China. This, however, might easily be due to differences in the exposure, orange trees growing in a forest often being much taller than those in the open without shade.

More material and, above all, ripe fruits will be needed to decide definitely whether the Khasi "wild orange" belongs to *Citrus ichangensis*. It is certainly much more closely related to this latter species than to any other. For the present it seems best to consider it as a subspecies of the Ichang lemon. The technical diagnosis is as follows:[1]

Citrus ichangensis latipes Swingle.

Differs from *C. ichangensis* in having the leaves more variable in size and shape with the tips acute, not caudate, the flowers in few-flowered (3 to 5) panicles instead of solitary, and the fruits oblate instead of prolate spheroidal in shape.

DISTRIBUTION: ASSAM, NORTHEASTERN INDIA. KHASI HILLS

Living Bridge,[2] Hooker and Thomson, September 2, 1850, "small orange, *wild*," fruits, Kew; **Myrung Wood** (altitude 5,700 ft.), J. D. HOOKER and T. THOMSON, July 6, 1850, "Aurant. Tree 30 ped. alt. Frt size of a walnut," fruits, Kew; **Moflong** (altitude 6,000 ft.),[3] J. D. HOOKER and T. THOMSON, July, 1850, fruits, Kew; **Moflong**(?), J. D. HOOKER and T. THOMSON, "*Citrus latipes* H. f. and T. Regio temp. (indig.) alt. 5,000–6,000 ped.,"[4] no date, sterile twigs, Harvard (Gray Herbarium); **Khasi Hills,** C. B. CLARKE No. 21879 (Collector Rutton), 1873, flowers, British Museum.

DETAILED DESCRIPTION OF CITRUS ICHANGENSIS LATIPES

The leaves of *Citrus ichangensis latipes* vary greatly in size and shape, ranging from 65 to 152 by 12 to 48 mm., the length varying from three to seven times the width. The petioles in particular, though always broadly winged, are distinctly more variable than in the Chinese material. They vary from oblanceolate linear to spatulate oblong or elongate obcordate. The largest petioles occur in a fruiting branch from Living Bridge (the type specimen of the subspecies in Kew Herbarium); they are spatulate oblong, 75 to 92 by 44 to 48 mm., tapering rapidly into a marginate base 4 to 6 mm. long. A specimen from Moflong (in Kew Herbarium) has oblanceolate-linear petioles 30 to 45 by 10 to 16 mm. The other material is intermediate between these two extremes, and one twig from Myrung Wood (in Kew Herbarium) has elongate-obcordate petioles 35 to 45 by 16 to 20 mm. in size. The blades of the leaves vary from ovate to lanceolate and are 35 to 65 by 14 to 40 mm.; in some specimens the laminæ are decidedly smaller than the winged petiole, while in others the reverse is true.

[1] **Citrus ichangensis latipes,** subsp. nov.—*Citrus ichangensis* affinis, foliis acutis haud caudatis, floribus in paniculatis pauci-floribus (3–5) dispositis, fructibus oblatis.

[2] This is the type of the subspecies.

[3] Cf. Hooker, J. D., 1854, Himalayan Journals, London, v. 2, p. 288, 292, 323.

[4] This specimen has only a lithographed label with manuscript additions. One of the twigs has extremely ong and slender winged petioles like the specimen from Moflung in Kew Herbarium and probably was a part of the same collection. The other specimens of Hooker and Thomson in Kew Herbarium have this same label carrying in manuscript the name "*Citrus latipes* H. f. and T.," but have in addition original labels giving the exact locality and date of collection.

PREVIOUSLY PUBLISHED NOTICES OF THE SUBSPECIES

Very little has been published concerning this plant. The first notice seems to have been given it in 1874 by Edmund Goeze, who lists it as "*Citrus latipes* Hook. fil. et Th. A very peculiar species from India."[1]

In 1875 J. D. Hooker, in his Flora of British India,[2] cited it under the name "*C. latipes* Hook. f. and Thoms. Herb. Ind. Or." as a synonym of *C. histrix* DC., an erroneous determination doubtless due to the lack of flowers and mature fruits in the Khasi material at his disposal. The name "*Citrus latipes* Hook. f. and Thoms." is a *nomen nudum* without standing in taxonomy, since no description has been published under it.

Efforts are being made to secure ripe fruits and viable seeds of this interesting tree, which, like the Chinese form of the species, promises to be very cold resistant.

POSSIBLE USES OF CITRUS ICHANGENSIS

Mr. E. H. Wilson informs the writer that the form of this species cultivated in the Ichang region yields an excellent fruit known to foreign residents of the Yangtze Valley as the "Ichang lemon." These fruits are shipped down the river to Hankow and west well into Szechwan, and are so much esteemed as to command good prices.

The large size of the seeds makes it probable that *Citrus ichangensis* will produce very vigorous seedlings, and hence it is likely to be of value as a stock on which to graft other citrous fruits. These numerous large seeds, which promise to render this plant so valuable as a stock, have the drawback of greatly reducing the proportion of juice, because of the space they take up. However, experience has shown that it is relatively a simple matter to breed nearly seedless varieties of citrous fruits by selection or hybridization.

So far as is now known, *Citrus ichangensis* is native farther north than any other evergreen species of Citrus, only the deciduous *Citrus trifoliata* having a more northerly range. Besides having the northernmost range of any known evergreen species of Citrus it occurs at the highest altitudes reported for any wild species of the genus. In the Hsingshan District, in latitude 31° 10′, Mr. Wilson collected this plant at an altitude of 4,200 feet, and Père Cavalerie found it in central Kweichow at a height of 5,577 feet.

At Moflong in the Khasi Hills, Hooker and Thomson found the Khasi subspecies growing wild at an altitude of 6,000 feet. As to the winter climate of this part of Assam J. D. Hooker says:

> In November the vegetation above 4,000 feet turns wintry and brown, the weather becomes chilly, and though the cold is never great, hoarfrost forms at Churra, and water freezes at Moflong.[3]

[1] Translation from Goeze, Edmund, 1874. Ein Beitrag zur Kenntniss der Orangengewächse. Hamburg, p. 19.

[2] Hooker, J. D., 1875. Flora of British India. v. 1, London, p. 515.

[3] Hooker, J. D., 1854. Himalayan Journals, v. 2, London, p. 323.

Around Ichang, which is situated at an altitude of about 2,000 feet, the winters may be severe, as is proved by the meteorological record for the year 1888, which showed an absolute minimum of 22° F. (−5.6° C.) in February.[1] It is highly probable that a series of observations extending over a number of years would show that the minimum temperature occasionally falls decidedly lower than this. It would undoubtedly be colder at an altitude of 4,200 feet in the near-by Hsingshan District, where this species grows wild.

Mr. Wilson, who knows the climate of this part of China well, is confident that the "Ichang lemon" will prove to be one of the hardiest citrous fruits. Add to this the fact that the fruit is of a quality good enough to cause it to be exported to cities several hundred miles distant and it is obvious that this strikingly distinct new species of Citrus promises to be of value as a hardy substitute for the lemon, as well as a vigorous and hardy stock for other citrous fruits, and is eminently deserving of the attention of experimenters for use in the breeding of new types of hardy citrous fruits now so much in demand in this and other countries.

Its discovery in a part of China as accessible as Ichang is a further proof of the rich harvest of new species of plants that awaits the botanist and agriculturist in China.

DESCRIPTION OF PLATE

PLATE I. *Citrus ichangensis* Swingle: The type specimen from Hsingshan District, Hupeh Province, China, E. H. Wilson, No. 2230, May 7, 1907; in the herbarium of Arnold Arboretum; natural size.

[1] Doberck, William, 1889. Meteorological observations made at Ichang, China, and at South Cape Formosa, in 1888. Quart. Jour. Roy. Met. Soc. [London], v. 15, no. 72, p. 242.

CYSTICERCUS OVIS, THE CAUSE OF TAPEWORM CYSTS IN MUTTON

By B. H. RANSOM,
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INTRODUCTION

It has been known for nearly half a century that cysticerci occur in mutton, but they have generally been looked upon as zoological curiosities rather than parasites of real economic importance; in fact, it seems that this opinion has been so commonly accepted as an established truth that a systematic examination of sheep for such cysticerci, or measles, like that given cattle and hogs, has been considered unnecessary by meat-inspection authorities. So far as this country is concerned, however, the belief that sheep measles are rare has been lately discovered to be quite erroneous. Instead of being rare, sheep measles have been found to be of much the same order of frequency as beef measles and far more common than pork measles, which are almost unknown in the United States. Where the presence of measles has been carefully looked for, the percentage of affected sheep has run 2 per cent and over, and during the calendar year 1912 approximately 20,000 sheep carcasses were retained under Federal inspection at various abattoirs on account of measles, most of them during the last few months of the year.

In the light of these figures it is quite evident that the mutton cysticercus is far from being the unimportant parasite it is commonly assumed to be, and it is furthermore quite certain that as inspectors become generally more familiar with this parasite and with the proper methods of inspecting for its presence the percentage and gross number of cases found will materially increase.

As yet sufficient data are not at hand to indicate the extent of direct injury to sheep by the measles parasite, so that the chief practical importance of sheep measles recognized at the present time is in their relation to meat inspection and public health. Like beef and pork cysticerci, the mutton cysticercus is of special interest in meat inspection because it affects the musculature, that part of the animal which is at once the most valuable for food purposes and the most difficult to inspect thoroughly.

The beef and pork cysticerci are well known to be the intermediate stages of two species of tapeworms occurring in man. The question naturally arises, Is the mutton cysticercus likewise the intermediate stage of a human tapeworm? The leading foreign meat-inspection authorities have held that the mutton cysticercus is simply *Cysticercus cellulosae*, the pork cysticercus, in an unusual host, and have laid down identical

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regulations governing the disposal of affected hog and sheep carcasses. The American meat-inspection regulations, which are similar to, though necessarily somewhat more stringent than, the German regulations because of the lack of a Freibank system in this country, require the condemnation of carcasses heavily infested with *C. cellulosae* and permit slightly infested carcasses to be rendered into edible fat. As a condemned carcass is entirely destroyed for food purposes and as the value of a sheep carcass rendered into edible tallow is scarcely greater than that of one which has been condemned and made into fertilizer or other inedible products, a carcass infested with *C. cellulosae* in any degree whatsoever would be practically excluded from use as food under American regulations. Accordingly, if the mutton cysticercus were actually *C. cellulosae*, the 20,000 sheep carcasses in which muscle cysticerci were found last year would have been eliminated from the meat supply of the United States. Relatively this loss would not have been very great, and in actual money value it would not have exceeded $100,000. In the future, however, much greater losses would occur, because the more efficient methods of inspection which would be developed by experience would naturally lead to the detection of more nearly all the cases of sheep measles than the earlier, less efficient methods. The number of sheep affected with measles is probably considerably in excess of 1 per cent of the entire number slaughtered, and accordingly the loss on this account would be very large if anywhere near all the cases were found on inspection and if they were disposed of under the assumption that the parasite involved is *C. cellulosae*.

Shortly following the discovery of the first cases found last year, the writer undertook an investigation of the question of sheep measles, with the result that it was quickly proved that the parasite involved is certainly not *Cysticercus cellulosae*, though closely resembling it in some respects, and in due course of time it was definitely established that the mutton cysticercus is the larval stage of a dog tapeworm.

The question of sheep measles is therefore much less serious than it would be if the parasite were one transmissible to man, particularly if it were the rather dangerous *Cysticercus cellulosae*. So far as meat inspection is concerned, however, sheep measles, though less important as a public-health question, are almost as important as though the parasite involved were transmissible to human beings, because meat containing parasites of sufficient size to be noticeable is more or less objectionable as food for esthetic reasons if on no other account.

HISTORICAL SUMMARY

Considering critically the various statements which have appeared relative to muscle cysticerci in sheep prior to the recent investigations by the present writer, it may be noted in the first place that excepting one of Morot's (1899e)[1] cases (No. 3), which was quite evidently one of

[1] Bibliographic references in parentheses refer to the "Bibliography," pp. 54–57.

generalized coenurosis, there is no definite conclusive evidence that more than one species of parasite is concerned in sheep measles; hence the presumption is that the muscle cysticerci reported from sheep all belong to a single species. Taking into account the fact that it has now been proved by experiment that muscle cysticerci in sheep develop into tapeworms distinct from either *Taenia solium* or *T. hydatigena*, it is quite clear that none of the observers reporting muscle cysticerci in sheep has given sufficient evidence to show that the parasites in any instance were *Cysticercus cellulosae*, as they were held to be by some, or *C. tenuicollis*, as they were held to be by others, and not in all cases, *C. ovis*. Commonly the only evidence to support the observer's identification is a statement that the parasite showed the characters of *C. cellulosae* (Olt, Armbrüster, Colberg, Rickmann, Herter) or *C. tenuicollis* (Chatin, Glage). In a few cases measurements of the hooks have been recorded, but these apply equally as well or better to *C. ovis* than to *C. cellulosae* or *C. tenuicollis*. Bongert's report is of special interest in this connection, as he gives a photomicrograph of the hooks (fig. 1), comparison of which with the hooks of *C. cellulosae* shows that the hooks agree imperfectly, thus demonstrating the incorrectness of Bongert's positive opinion that the parasite was *C. cellulosae*. The opinion formerly held by the present writer (1908d) that certain partially grown muscle cysticerci with hooks not yet fully developed which had been found in a sheep were *C. cellulosae* on account of the presence of certain characters also found in *C. cellulosae* is likewise seen now to be quite erroneous.

FIG. 1.—*Cysticercus ovis:* Hooks, × 275. (After a photomicrograph by Bongert, 1899a, fig. 3.)

Railliet and Morot noticed that the hooks of a cysticercus resembling *Cysticercus cellulosae* from a sheep heart, though agreeing fairly well in size with *C. cellulosae* hooks, as shown by the measurements which they give, corresponded closely in form to those of *C. tenuicollis*. They accordingly so identified the cysticercus, at the same time, however, calling attention to the fact that the hooks are fewer in number than is usual in *C. tenuicollis* and that they are smaller, differences possibly to be attributed, according to their view, to the location of the parasite in the muscles instead of in the serous membranes. It is quite probable—in fact, not to be doubted—that the parasite in this case was *C. ovis*.

Not only have observers failed to give sufficient evidence that the mutton cysticerci in any case exactly agreed in morphology with *Cysticercus cellulosae* or *C. tenuicollis*, but they have also failed to produce experimental proof to support their identifications. *C. cellulosae* has never been produced experimentally in sheep by feeding *Taenia solium* eggs (Leuckart, Küchenmeister, Perroncito); nor, vice versa, has *T. solium* been produced in man as a result of ingesting mutton cysticerci (Chatin, Ransom[1]).

There is also no good evidence that *Taenia hydatigena* has ever been obtained as a result of feeding the mutton cysticercus to dogs. It is true that Chatin states that such is the case, but the evidence that the tapeworms were identical with those belonging to *Cysticercus tenuicollis* consists simply in Chatin's affirmation that they were the same, and there is no objective evidence at all to support this view. It also should be noted that no one has shown that segments of *T. hydatigena*, when fed to sheep, will produce muscle cysticerci. Leuckart, Küchenmeister, and others have found only *C. tenuicollis* as a result of such experiments.

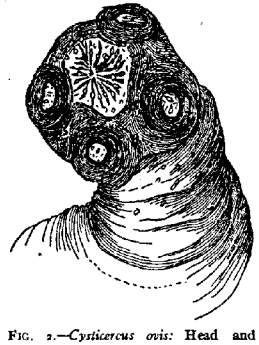

FIG. 2.—*Cysticercus ovis:* Head and neck, × 30. (After Cobbold, 1869a, p. 30, fig. 2.)

Cobbold's opinion that *Cysticercus ovis* is the larva of a human tapeworm, the so-called *Taenia tenella*, has never had any supporting evidence and, of course, is now entirely discredited. Cobbold, however, it is interesting to note, was quite correct in another opinion which he at one time held—namely, that it is probable that the adult of *C. ovis* occurs in one of the carnivora.

Most of the records of muscle cysticerci in sheep are based upon isolated cases in which the parasites have usually been more or less degenerate. Thus, Cobbold noted the presence of degenerated cysticerci in mutton on several occasions and described *Cysticercus ovis* on the basis of a single specimen (fig. 2) which had lost the caudal bladder before it came into his hands. Maddox described *C. oviparіens* (figs. 3 and 4) on the basis of one degenerated cysticercus. The number of cases seen by Möbius, reported by Küchenmeister, is not stated. Chatin apparently saw muscle cysticerci on several occasions, and some of these evidently were alive and undegenerated. Morot refers specifically to five cases and refers to an indefinite number of others, in all of which the parasites were degenerated and were recognized as cysticerci only from the character of the cysts. Railliet and Morot reported one case of a single, apparently undegenerated cysticercus in the heart of a sheep, and refer

[1] For an account of the present writer's experiments, see pp. 21–26.

to a similar case of cysticercus in the heart of a kid. The case reported by Olt and Bongert showed numerous cysticerci, some of which apparently were alive. In another case seen by Olt the parasites were all degenerate. Armbrüster found calcified cysticerci in 2 or 3 sheep out of a shipment of 16 head. One case of muscle cysticerci was found by Colberg in which numerous degenerated parasites were present.

In a case of cysticerci in a sheep heart reported by Railliet the parasites were very young, without hooks. Glage is the only author thus far who has given a detailed statistical record of the frequency of muscle cysticerci in sheep. His records, however, are based entirely upon the presence of degenerated cysticerci, and it is not improbable that he overlooked many cases of live cysticerci. He found 32 cases (1.45 per cent) among 2,198 carcasses in which the head muscles and hearts were examined and 16 cases (0.8 per cent) among 1,984 carcasses in which only the hearts were examined. Rickmann fails to state the number of cases observed. The cysticerci in the one case reported by the present writer in 1908 were undegenerate but only partly grown. Herter mentions one case and says that only nine cases of sheep measles were recorded in the meat-inspection reports of Prussia for the year 1909. Making a very liberal allowance for the number of indefinitely reported cases, the total number of individual cases of sheep measles reported in the literature prior to the recent investigations in this country is considerably less than 100, and in only a very few of these were the cysticerci at all numerous or present in a living, fully developed, undegenerated condition. It is accordingly not surprising that the identity of these parasites should have remained so long undiscovered, particularly in view of the fact that they have received but little attention from experienced parasitologists, who, moreover, have had very unsatisfactory material for study.

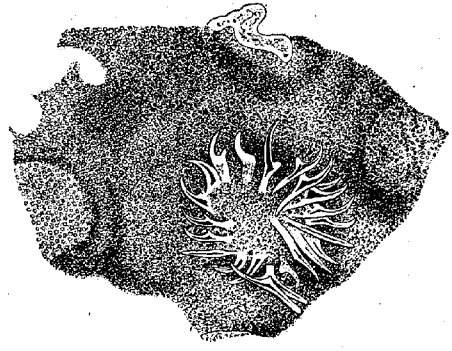

FIG. 3.—*Cysticercus oviparíens* (= *C. ovis*): Fragment of head, × 85. (After Maddox, 1873a, pl. 19, fig. 1.)

FIG. 4.—*Cysticercus oviparíens* (= *C. ovis*): Hooks, × 160. (After Maddox, 1873a, pl. 18, fig. 5.)

Cobbold, for example, apparently studied only one specimen (imperfect), and Railliet seems to have had only one fully developed undegenerated specimen for critical examination.

Up to the present time sheep measles have been reported from the following countries: England, Germany, France, Algeria, German Southwest Africa, New Zealand, and the United States.

In completing this brief critical summary of the literature, only a few words need be given concerning the morphology of the parasites. As already noted, morphological details have been omitted from most of the accounts given of the recorded cases. The measurements of the hooks given by Railliet and Morot correspond to *Cysticercus ovis*, as do Bongert's measurements and photomicrograph. Maddox was the first to observe the mammillated surface of the caudal bladder, which, however, has not been recognized as a distinctive difference between *C. ovis* and *C. tenuicollis*, except by the present writer (1908d), and apparently has escaped attention from other observers.

LIFE-HISTORY INVESTIGATIONS

Under date of February 29, 1912, Dr. S. E. Bennett, inspector in charge at Chicago, Ill., reported to the Bureau of Animal Industry that a number of sheep carcasses had been found to be infested with measles, and under date of March 1 Dr. O. B. Hess, inspector in charge at Seattle, Wash., also reported the finding of measles in several sheep carcasses. Specimens were forwarded to Washington from both stations for laboratory examination. The cysts in the specimens were all degenerate, but fragments of the caudal bladder of cysticerci were found, and in view of the presence of cuticular papillæ, which are likewise present on the caudal bladder of *Cysticercus cellulosae*, and in accordance with the opinion of German meat-inspection authorities as to the identity of mutton cysticerci, the diagnosis of *C. cellulosae* was made. Shortly following the first reports, information was received that out of 4,537 sheep slaughtered at Seattle, Wash., 79 carcasses were retained on account of measles, and that during a month at Chicago 224 carcasses were retained.

With this information at hand it was immediately apparent that the diagnosis of *Cysticercus cellulosae* could not be correct, for the reason that *C. cellulosae* and its tapeworm stage, *Taenia solium*, are exceedingly rare in the United States. Probably not more than a dozen cases of pork measles are found annually at any of the large stations, where the number of hogs slaughtered amounts to hundreds of thousands. It was unbelievable that a parasite so rare in its usual host should be so common in sheep. A few days spent in studying numerous specimens obtained at the abattoirs in Chicago developed the fact that the sheep-measle parasite was certainly not *C. cellulosae*, though in certain characters they were very similar. In some details of structure the muscle cysticerci

resembled *C. tenuicous*, but in other respects the two forms did not agree. Accordingly an experiment was undertaken to determine whether the parasites would develop in dogs and whether the tapeworms, if any developed, would prove to be *T. hydatigena* (the tapeworm corresponding to *C. tenuicollis;* also known as *T. marginata*, the marginate tapeworm of the dog), as affirmed by Chatin (1886a), who stated that he had obtained *T. marginata* by feeding mutton cysticerci to dogs, or whether they would prove to be some other species. Seven dogs were under observation in 1912. Five of these were fed cysticerci from sheep muscle, while two, as controls, were fed *C. tenuicollis* from the omentum or mesenteries of sheep. With three exceptions, as noted below in the records of the experiment, the dogs were given a dose of castor oil and the feces examined for the presence of parasite eggs before the cysticerci were fed. During the experiment the dogs were nourished on dog biscuits, corn-meal mush, and some cooked meat but no mutton and were confined in separate kennels.

Dog No. 1.—A grayish brown young female. Fed muscle cysticerci from sheep. Feces were not examined before feeding cysts.

March 25. Fed 1 cyst from heart muscle of sheep.
March 27. Fed 1 cyst from heart muscle of sheep—probably dead.
March 28. Fed 3 cysts from heart muscle of sheep.
March 29. Fed 3 cysts from heart muscle of sheep.
March 30. Fed 3 cysts from heart muscle of sheep—1 probably dead.
April 1. Fed 1 cyst from diaphragm of sheep—probably dead.
April 2. Fed 1 cyst from body muscle of sheep.
April 3. Fed 2 cysts from heart muscle of sheep.
April 24. Fed 1 cyst from heart muscle of sheep.
April 29. Fed 2 cysts from heart muscle of sheep.
May 2. Fed 1 cyst from heart muscle of sheep.
May 21. Fed 1 cyst from heart muscle of sheep.
May 22. Fed 1 cyst from heart muscle of sheep.
May 24. Fed 2 cysts from heart muscle of sheep.

Total.. 23 cysts.

June 22. Eggs of *Toxascaris* and a tapeworm segment found.
June 27. Tapeworm segments found in feces.
July 24. Chloroformed. About 25 individuals of *Toxascaris* in upper half of jejunum. Seven tapeworms, all with gravid segments, in ileum. Heads attached near upper end of ileum, about 65 cm. from ileocecal valve. Length of tapeworms, 45 to 55 cm.

Dog No. 2.—A white-and-tan young female. Fed *Cysticercus tenuicollis* from peritoneum of sheep. Feces were not examined before feeding cysts.

April 5. Fed 3 cysts.
April 9. Fed 4 cysts.
April 11. Fed 1 cyst.
April 18. Fed 7 cysts.
May 10. Fed 1 cyst.
May 28. Fed 5 cysts.

Total.. 21 cysts.

June 22. Eggs of tapeworm and *Toxascaris* eggs found.
July 11. Two tapeworm segments found in feces.
July 26. Chloroformed. Numerous individuals of *Toxascaris* in jejunum and duodenum. Nine tapeworms with gravid segments; one of the tapeworms was about 110 cm. long. The tapeworms were attached about 8 cm. below the pylorus, 80 cm.

from the ileocecal valve, and the posterior ends of the worms extended to within 40 cm. of the ileocecal valve.

Dog No. 3.—A young black-and-white female. Fed muscle cysticerci from sheep. March 29. Received one-half ounce of castor oil at 5 p. m. March 30. Feces were examined with negative results.

April 5. Fed 1 cyst from myocardium.
April 6. Fed 3 cysts from myocardium.
April 10. Fed 3 cysts from myocardium.
April 11. Fed 6 cysts from myocardium.
April 13. Fed 1 cyst from myocardium.
April 29. Fed 1 cyst from myocardium.
May 2. Fed 1 cyst from myocardium.
May 21. Fed 1 cyst from myocardium.
May 23. Fed 1 cyst from myocardium.
May 24. Fed 3 cysts from myocardium.

Total... 21 cysts.

June 11. Feces examined but no eggs found.

No segments or eggs have been found (prior to July 22).

July 22. Chloroformed. Four tapeworms attached 25 to 35 cm. from the ileocecal valve, one of them with gravid segments, about 45 cm. long when extended, other three not over 2 to 5 cm. long. Three very short tapeworms in cecum. In large intestine a string of about 10 gravid segments. Total number of tapeworms, seven. Three individuals of *Toxascaris* in jejunum.

Dog No. 4.—A young red male. Fed muscle cysticerci from sheep. March 29. Received one-half ounce of castor oil at 5 p. m. March 30. Feces were examined and *Toxascaris* eggs found.

April 18. Fed 1 cyst from myocardium of sheep.
April 19. Fed 1 cyst from cheek muscle of sheep.
April 23. Fed 16 cysts—3 from myocardium and 13 from muscles of sheep. Hooks were well developed.
April 24. Fed 1 cyst from myocardium of sheep.
May 2. Fed 1 cyst from myocardium of sheep.
May 15. Fed 1 cyst from myocardium of sheep.
May 21. Fed 1 cyst from myocardium of sheep.
May 24. Fed 2 cysts from muscles of sheep.

Total.... 24 cysts.

June 11. Eggs of *Toxascaris*, but no tapeworm eggs found.

June 27. Three broken tapeworm segments found in feces.

July 24. Chloroformed. Two individuals of *Toxascaris* in upper part of jejunum. Sixteen or seventeen tapeworms extending down into lower part of colon. None attached more than 4 cm. above ileocecal valve. One attached in cecum. None with gravid segments. Length, 20 to 50 cm.

Dog No. 5.—A medium-sized brindled male. Fed muscle cysticerci from sheep. March 29. Received one-half ounce of castor oil at 5 p. m. March 30. Feces were examined with negative results.

April 23. Fed 20 cysts from muscles of sheep. Hooks were well developed.
April 24. Fed 1 cyst from myocardium.
May 2. Fed 1 cyst from myocardium.
May 15. Fed 1 cyst from myocardium.
May 21. Fed 1 cyst from myocardium.
May 24. Fed 2 cysts from muscles of sheep.

Total.. 26 cysts.

June 11. Tapeworm eggs and eggs of *Toxascaris* were found in feces.

June 19. Two or three segments found in feces.

July 24. Chloroformed. No tapeworms found. Numerous dead fly larvæ in colon and small intestine. Numerous *Toxascaris* in upper part of jejunum and in duodenum.

Dog No. 6.—A medium-sized white male. Fed muscle cysticerci from sheep. March 29. Received one-half ounce of castor oil at 5 p. m. March 30. Feces were examined and *Toxascaris* eggs found.

April 23. Fed 20 cysts from muscles of sheep. Hooks well developed.
April 24. Fed 1 cyst from myocardium.
May 2. Fed 1 cyst from myocardium.
May 15. Fed 1 cyst from myocardium.
May 21. Fed 1 cyst from myocardium.
May 24. Fed 2 cysts from muscles of sheep.

Total.. 26 cysts.

June 11. Tapeworm eggs and eggs of *Toxascaris* were found in feces.

June 19. Two tapeworm segments were found in feces.

July 26. Chloroformed. Eight or nine tapeworms with gravid segments, one of them measuring 1 meter in length. Heads attached 135 cm. above the ileocecal valve, and posterior ends of the worms extending to a distance of 55 cm. from the ileocecal valve. Numerous individuals of *Toxascaris* in jejunum and in duodenum.

Dog No. 7.—A medium-sized black-and-white spotted female. Fed *Cysticercus tenuicollis* from peritoneum of sheep. Feces were not examined before feeding cysts.

April 9. Fed 4 *Cysticercus tenuicollis*
April 18. Fed 7 *Cysticercus tenuicollis*.
May 28. Fed 7 *Cysticercus tenuicollis*.

Total.. 18.

June 22. Feces show a few young tapeworm segments.

July 11. Found several portions of tapeworms; each portion contained from 2 to 20 segments.

July 26. Chloroformed. Three or four individuals of *Toxascaris* in duodenum and jejunum. Ten tapeworms with short strobila not over 10 mm. long in duodenum.

In continuation of the experiment with the dogs another experiment was undertaken for the purpose of recovering the cystic stages of the tapeworms. Ten lambs were purchased from a lot of thirty-nine, the remainder of which were slaughtered at one of the packing houses in Chicago and found to be free on post-mortem examination from both muscle cysticerci and *Cysticercus tenuicollis*. One of the ten died shortly after purchase and consequently was not used in the experiment. The sheep were kept during the experiment in floored and covered pens in one of the sheep barns at the Union Stock Yards, Chicago, and were fed dry hay and occasionally oats and received water piped from the water mains. The identity of the various lambs was maintained by numbered ear tags.

Lamb No. 1.—July 24. One half of a gravid segment from a tapeworm out of dog No. 1 (a dog which had been fed muscle cysts) was cut in pieces and given in a drench with water.

August 7. Dr. Day reported that lambs Nos. 1, 2, 3, and 5 were more or less sick but would probably recover.

August 21. Is very thin and has a diarrhea, but is feeding well.

October 15 (eighty-three days after feeding). Chloroformed. In poor flesh, very little fat. Cysticerci were found in the panniculus carnosus. Forty-two degenerate cysts were counted in the diaphragm; ten degenerate cysts in the wall of the esophagus. Several cysts in anterior lobes of lungs, 2 to 3 mm. in diameter; contents caseous. One contained a small dead cysticercus, 1 mm. in diameter; rudiment of head present. Numerous small degenerate cysts in heart. Numerous cysticerci in muscles of mastication; some living, others degenerate. A few nodules in the wall of the rumen, and one in the wall of the fourth stomach, 2 to 4 mm. in diameter, hard, shotlike, with thick wall and cheesy contents. No cysticerci were found in these cysts. Nodules present on wall of cecum, probably *Oesophagostomum*. No cysticerci found in these nodules. Many degenerate cysts among those present in the musculature in various parts of the body. The sizes of 13 live cysts measured in situ were as follows, in millimeters: 9 by 3.5, 8 by 3, 7 by 4, 7 by 3, 6 by 3, 5 by 4, 4 by 2.5, 5 by 3, 7 by 4, 8 by 4, 8 by 3, 6 by 2.5, and 9 by 4. A cyst 5 or 6 mm. in diameter with thick leathery capsule contained a live cysticercus which was active under the microscope. This cysticercus was not fully developed, only the blade of the hooks being formed. Other cysticerci showed fully developed hooks, and cysticerci from degenerate cysts showed in some cases hooks not yet fully formed.

Lamb No. 2.—July 26. A gravid segment from a tapeworm out of dog No. 6 (a dog which had been fed muscle cysts) was given in a drench with water.

August 7. Dr. Day reported that lambs Nos. 1, 2, 3, and 5 were more or less sick but would probably recover.

August 17 (twenty-two days after feeding). This animal died, but its death was not reported until two days later, when decomposition was so far advanced that Dr. Day did not attempt a post-mortem examination.[1]

Lamb No. 3.—July 26. A gravid segment from a tapeworm out of dog No. 6 (a dog which had been fed muscle cysts) was given in a drench with water.

August 7. Dr. Day reported that lambs Nos. 1, 2, 3, and 5 were more or less sick but would probably recover.

August 18 (twenty-three days after feeding). This animal died. Decomposition was far advanced the following day when a post-mortem examination was made, but some of the masseter muscle and some of the muscle of a hind leg were obtained. Dr. Day reports that cysts in the masseter muscle were quite well formed and contained a tiny white spot just visible to the eye. Microscopic examination by Dr. Day showed that the head was not well formed, but papillæ were evident on the caudal bladder.

Lamb No. 4.—July 24. A gravid segment (cut in pieces) from dog No. 1 (a dog which had been fed muscle cysticerci) was given in a drench with water.

August 7. In very bad condition; probably will die.

August 11 (eighteen days after feeding). Dead.

August 12. An incomplete post-mortem examination was made by Dr. Day. Advanced decomposition. A number of cysts were obtained from the masseter muscles.

Lamb No. 5.—July 24 a gravid segment from a tapeworm out of dog No. 3 (a dog which had been fed muscle cysticerci) and on July 26 two gravid segments from a tapeworm out of dog No. 6 (a dog which had been fed muscle cysticerci) were given in a drench with water, a total of three segments.

August 7. Dr. Day reported that lambs Nos. 1, 2, 3, and 5 were more or less sick but would probably recover.

[1] In prior publications (Ransom, 1913, p. 78; 1913, p. 31) it was erroneously stated that all of the lambs which had been fed eggs of the muscle cyst tapeworm showed tapeworm cysts in the muscles. The condition in lamb No. 2, of course, was not determined, as no autopsy was made on this animal. The statement (Ransom, 1913, p. 31) that the lambs died in 14 to 22 days after feeding is also inaccurate. It should be 13 to 23 days.

August 12 (ten days after feeding). Dead. Post-mortem examination by Dr. Day the following morning showed a large number of cystic parasites in the masseter muscles, heart, tongue, and diaphragm. There were also numerous cystic parasites in the skeletal muscles and a few hemorrhagic spots.

Lamb No. 6.—July 24, four segments from tapeworms out of dogs Nos. 1 and 3 (dogs which had been fed muscle cysticerci), two segments from each dog, and July 26 six segments from tapeworms out of dog No. 6 (a dog which had been fed muscle cysticerci) were given in a drench with water, a total of ten segments.

August 5. Appears ill and out of condition.

August 6 (thirteen days after feeding). Dead. Post-mortem by Dr. Day showed that the parasites had already migrated to the muscles, and were found as very minute cysts, more numerous in the heart and masseter muscles than elsewhere. There were about 25 c. c. of fluid in the pericardium. The heart was very thickly studded with minute cysts. There were about 350 c. c. of fluid in the peritoneal cavity. A careful examination of the fluid was made, but no parasites were found. The liver appeared normal.

Lamb No. 7.—July 26. A gravid segment from a tapeworm out of dog No. 2 (a dog which had been fed *Cysticercus tenuicollis* from the peritoneum of sheep) was given in a drench with water.

August 21. Reported by Dr. Day as doing well.

October 18 (eighty-four days after feeding). Chloroformed. Animal in poor flesh. Twelve to fifteen cysts on omentum and mesenteries, two of which are alive, the others degenerate. One degenerate cyst under peritoneum in pelvic cavity. Degenerate cysts vary in size up to a maximum of 20 mm. in diameter. Contain dead cysticerci, a small amount of colorless serous fluid and flocculent débris or a greenish, caseous material. The live cysticerci measure 8 by 15 mm., and show the usual macroscopic characters of *Cysticercus tenuicollis*. A few degenerate cysticerci of small size on the surface of the liver. No cysticerci in the muscles, lungs, or other organs, except as noted above. *Oesophagostomum* nodules on the intestine.

Lamb No. 8.—July 26. Ten gravid segments from a tapeworm out of dog No. 2 (a dog which had been fed *Cysticercus tenuicollis* from the peritoneum of sheep) given in a drench with water.

August 21. Reported by Dr. Day as doing well.

October 17 (eighty-three days after feeding). Chloroformed. Animal in poor flesh. A considerable number of small degenerate cysticerci on surface and in depths of liver. About 25 degenerate cysts on omentum and mesenteries. One live cysticercus on omentum about 12 mm. in diameter shows the usual macroscopic characters of *Cysticercus tenuicollis*. One degenerate cyst on tendinous portion of diaphragm (abdominal surface). Small nodules in lungs, one of which contained a young dead cysticercus showing under the microscope transverse ridges on the cuticle of the caudal bladder. Synthetocaulus nodules also present on the lungs. Several pockets in the lungs with fibrous walls containing greenish pus. The contents of these pockets were examined, but no cysticerci were found. Heart and muscles were free from parasites. A cyst from the omentum, 8 mm. in diameter, with thick fibrous wall contains a dead cysticercus with evaginated head and bladder about 3 mm. in diameter. Two cysts from the omentum or mesentery, 5 and 6 mm. in diameter, respectively, contain each a dead cysticercus and a small amount of colorless serous fluid and flocculent débris. The other degenerate cysts are similar, except the contents in some are greenish, caseous. Their size varies from 2.5 to 10 mm., and all have thickened walls ¼ to ¾ mm. thick. The degenerate cyst from the tendinous portion of the diaphragm is flattened, 8 mm. in diameter. Its wall is thin, and it contains a dead *Cysticercus tenuicollis* and a small amount of serous fluid and white flocculent matter.

Lamb No. 9.—A check animal, not fed with tapeworm segments.

October 18. Chloroformed. In poor flesh. Free from parasites except *Oesophagostomum* nodules on the intestines.

The following experiments relating to the possibility of the development of sheep-measle tapeworms in man have been caried out, the writer being the subject.

On March 6, 1913, a cysticercus about 5 mm. in diameter, and March 14 another cysticercus of similar size, both from sheep hearts, were swallowed. Both cysticerci were alive and in good condition, exhibiting lively contractions of the caudal bladder when viewed under the microscope. On March 28 eight fully developed cysticerci were isolated from a sheep carcass heavily infested with *Cysticercus ovis* and swallowed. These cysticerci were apparently in good condition and were undoubtedly alive, as they showed active movements under the microscope. No signs of tapeworm infestation have appeared in the case of the writer.

SUMMARY OF LIFE-HISTORY EXPERIMENTS

Five dogs were each fed from 21 to 26 muscle cysticerci from sheep on various dates between March 25 and May 24. Subsequent to June 11, tapeworm eggs or segments were demonstrated in the feces, or tapeworms were found post-mortem in the case of all five dogs. No tapeworms were found in one of the dogs (No. 5) post-mortem, but a month earlier this dog had shown tapeworm eggs and segments in the feces. In the case of two of the dogs (Nos. 5 and 6) it was evident that the tapeworms had reached egg-producing maturity within seven weeks, as the earliest feeding of cysticerci was on April 23, eggs being demonstrated in the feces on June 11. The number of tapeworms recovered varied from 7 to 16.

Two dogs were fed *Cysticercus tenuicollis*, 18 and 21 cysticerci, respectively, between April 5 and May 28. The first tapeworm eggs were found in the feces on June 22. On post-mortem examination 9 tapeworms were found in one dog and 10 in the other.

Six lambs (Nos. 1 to 6) were fed with gravid segments of tapeworms from the dogs which had been fed *Cysticercus ovis*, two (Nos. 7 and 8) with gravid segments of tapeworms from one of the dogs which had been fed *C. tenuicollis*, and one (No. 9) was retained under the same conditions as the others but without receiving any cysticerci. Lambs Nos. 1 to 6 received ½ to 10 segments, and lambs Nos. 7 and 8, 1 and 10 segments, respectively. Of the former all but the one receiving half a segment died in 13 to 23 days after feeding, the one receiving 10 segments being the first to die, followed by one receiving 1 segment (death in 18 days), then by one receiving 3 segments (death in 19 days), then by two more receiving 1 segment each (death in 22 and 23 days, respectively), leaving the lamb which received half a segment to survive until killed—83 days after feeding. Both of the lambs fed with segments of *Taenia hydatigena* (adults

of *C. tenuicollis*) survived until killed at the close of the experiment. All but one of the lambs (No. 2), which died 22 days after feeding, were examined post-mortem.

Omitting this lamb from consideration, all of the lambs which received segments from the tapeworms produced by feeding muscle cysticerci showed cysticerci in their muscles when examined. Those found in the lamb which died 13 days after feeding were very small; those in the lamb which died 23 days after feeding were somewhat farther along in development, the beginnings of the head being already evident. Eighty-three days after feeding, the muscle cysticerci were found to have reached full development; some which had fully developed were already more or less degenerated, and some were found which had begun to degenerate before they reached their full development. In addition there were present live cysticerci which had not yet fully developed.

The lambs which had been fed segments of *Taenia hydatigena* showed a few *Cysticercus tenuicollis*, most of which were degenerate. In both animals there were small degenerate cysticerci on the liver. There were no visible lesions of the liver in the lambs fed segments of *T. ovis*. No *C. tenuicollis* was found in any of the lambs fed segments of *T. ovis*, and no *C. ovis* in the lambs fed segments of *T. hydatigena*. The check lamb showed neither *C. tenuicollis* nor *C. ovis*, and neither of these parasites was found at the post-mortem inspection of the remainder of the lot from which the experiment sheep had been selected.

Since these experiments show that muscle cysticerci in sheep resembling *Cysticercus cellulosae* and corresponding to the form described by Cobbold as *C. ovis* develop into tapeworms when swallowed by dogs, it has been definitely proved that these cysticerci are not *C. cellulosae*. The adult of *C. cellulosae* (*Taenia solium*) does not occur in dogs; moreover, the tapeworms which were produced in the dogs are quite different from *T. solium*. Furthermore, the experiments prove that the muscle cysticercus and its adult stage are specifically distinct from *C. tenuicollis* and *T. hydatigena*. It appears that the ingestion of one or more gravid segments of *T. ovis* is likely to prove fatal to sheep.

Attempts to produce tapeworms in man by feeding mutton cysticerci failed. On three occasions live mutton cysticerci were swallowed by the writer, a total of 10 cysticerci being ingested. No evidence of tapeworm infestation has since appeared. This experiment tends to prove that *Cysticercus ovis* is not transmissible to man.

SYNOPSIS OF LIFE HISTORY

The adult of *Cysticercus ovis* is a tapeworm (*Taenia ovis*) which occurs in the intestine of dogs. Since the parasites which live on dogs as a rule also thrive on wolves, and, since coyotes and other wolves frequently

devour sheep, it is quite likely that *T. ovis* also occurs in coyotes and other wolves as well as in dogs. In view of the fact, however, that dogs come in much closer relations with sheep it seems quite evident that dogs are chiefly responsible for the transmission of the parasite to sheep. It is possible though rather unlikely that the tapeworm occurs in other carnivores than dogs and wolves. There is little likelihood that the parasite is transmissible to man, and for all practical purposes its nontransmissibility to man may be considered an established fact. No such tapeworm has been reported from man, and, moreover, there are no authentic cases of the occurrence in man of any dog tapeworm belonging to the genus *Taenia*. Furthermore, Chatin has noted that the swallowing of muscle cysticerci from sheep failed to result in infestation in his case. The present writer, as already noted, has likewise on three occasions swallowed live and active muscle cysticerci from sheep without resulting infestation (p. 26).

Following the ingestion of the eggs of the tapeworm by sheep, the parasites reach the muscles in less than 13 days; they either do not pass through the liver or, unlike *Cysticercus tenuicollis*, leave no trace of their passage through this organ. In less than three months (83 days) the cysticerci reach their full development. As early as seven weeks after the ingestion of the cysticercus by a dog, its development to the mature egg-producing tapeworm may be complete. The development therefore appears to be somewhat more rapid than in the case of *Taenia hydatigena*, which was found by Leuckart (1856a) to require from 10 to 12 weeks. No doubt, however, the period required for development is subject to great variation, and though seven weeks is perhaps near the minimum for *T. ovis*, the period very likely may be greatly prolonged, as has been noted by Hall (1911, p. 510) in the case of the gid tapeworm.

ZOOLOGICAL DESCRIPTION OF THE SHEEP-MEASLE PARASITE

Taenia ovis (Cobbold, 1869) Ransom, n. comb., 1913.

1869: *Cysticercus ovis* Cobbold, 1869a, p. 30, fig. 2 (in *Ovis aries*; England).
1873: *Cysticercus ovipariens* Maddox, 1873a, p. 245–253, pl. 18, figs. 1–15, 17–18, pl. 19, fig. 1 (in *Ovis aries*; England).
1878: *Cysticercus cellulosae* of Küchenmeister, 1878, in Küchenmeister and Zürn, 1878–1881a, p. 104 (apparent misdetermination of *C. ovis;* in *Ovis aries;* Germany).
1885: *Cysticercus tenuicollis* of Chatin in Railliet, 1885a, p. 234 (apparent misdetermination of *C. ovis;* in *Ovis aries;* France).
1886: *Cysticercus oviparus* Leuckart 1886d, p. 498 (for *C. oviparieus*).
1913: *Taenia ovis* (Cobbold) Ransom, 1913.

SPECIFIC DIAGNOSIS OF TAENIA.

Larval stage.—An oval cysticercus (Pl. II, fig. 1) 3.5 by 2 mm. to 9 by 4 mm. in diameter. Head and neck invaginated from the wall of the caudal bladder not at one end but about midway between the ends. Membrane of bladder very thin; with small mammillate projections; not corrugated transversely (fig. 5 and fig. 6, *a*). Neck transversely corrugated, coiled spirally when invaginated, 1 to 5 mm. long when evaginated. Head 500 to 800μ in width; suckers oval, 240 to 320μ in diameter; rostel-

lum prominent, 275 to 375μ in diameter. Hooks (fig. 6) 24 to 36 in number, commonly 28 to 32, arranged in a double crown of alternating large and small hooks. Hooks rather slender (more slender and more lightly built than those of *Cysticercus cellulosae*); dorsal root of large hooks longer than the blade; in both large and small hooks a more or less well-marked outward curving of the dorsal border of the hook in the transitional region between the blade and dorsal root; ventral root of small hooks transversely enlarged, not bifid but sometimes presenting a faint median groove. Large hooks 156 to 188μ long, average 173μ; blade (from point of blade to tip of ventral root measuring in a straight line) 68 to 84μ, average 78μ (based on measurements of 24 hooks, fully developed or nearly so, from 10 cysticerci taken from various sheep and 13 hooks from the heads of 4 adult worms). Small hooks 96 to 128μ long, average 113μ; blade (from point of blade to tip of ventral root measuring in a straight line) 48 to 60μ, average 57μ (based on measurements of 26 hooks, fully developed or nearly so, from 11 cysticerci taken from various sheep and 10 hooks from the heads of 4 adult worms).[1]

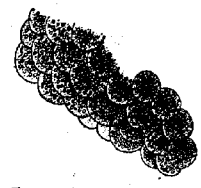

FIG. 5.—*Cysticercus ovipariens* (=*C. ovis*): Papillæ on caudal bladder, × 160. (After Maddox, 1873a, pl. 18, fig. 15.)

Calcareous corpuscles numerous in the neck, less numerous in the head, and very rare in the caudal bladder.

Adult stage (Pl. II, fig. 3; text figs. 7, 8, 9, and 10).—Length of living worms with gravid segments, 45 to 110 cm. Length (preserved material), 14 to 53 cm.; maximum width, 4 to 8.5 mm.; terminal segments, 2.5 to 15 mm. long by 4 to 6 mm. broad, usually longer than broad (measurements of 17 specimens with gravid segments). Strobila tends to twist in the form of a spiral. Head 0.8 to 1.25 mm. in breadth; neck, 0.65 to 0.9 mm. wide (measurements of 26 preserved specimens). Rostellum 375 to 430μ in diameter (8 specimens). Suckers 270 to 320μ in diameter (4 specimens). Number, arrangement, shape, and size of hooks as in larva. Segments with convex lateral borders, in consequence of which the edge of the strobila commonly presents a scalloped outline whose regularity is broken by the protuberant genital papillæ. The genital papillæ are irregularly alternate and are situated posterior of the middle of the segment; in gravid segments they may attain a diameter of over 1 mm. and a height of three-fourths of a mm. Genital sinus large, varying in depth and width up to a maximum of about 400μ. Cirrus pouch 450 to 550μ long; inner end near the outer side of the ventral longitudinal excretory vessel. The testicles are distributed in an area which extends anteriorly to the anterior limits of the segment and laterally to the longitudinal excretory vessels. This area is bounded posteriorly by a curved line which in sexually mature segments intersects the median line at a distance from the anterior border of the segment varying from a little more than a third to a little less than half the length of the segment and intersects the longitudinal excretory vessels a short distance in front of the posterior border of the segment, thus leaving an approximately semicircular space entirely free from testicles, most of which is occupied by the ovary. Behind the latter is the so-called yolk gland. The ovary is bilobed, the

[1] *Measurements of 26 hooks.*

Member.	Larva.	Adult.	Member.	Larva.	Adult.
Large hooks:	μ.	μ.	Small hooks:	μ.	μ.
Entire	156 to 188	160 to 184	Entire	96 to 120	104 to 128
Average	173	173	Average	112	116
Blade	76 to 80	68 to 84	Blade	52 to 60	48 to 60
Average	79	75	Average	57	57

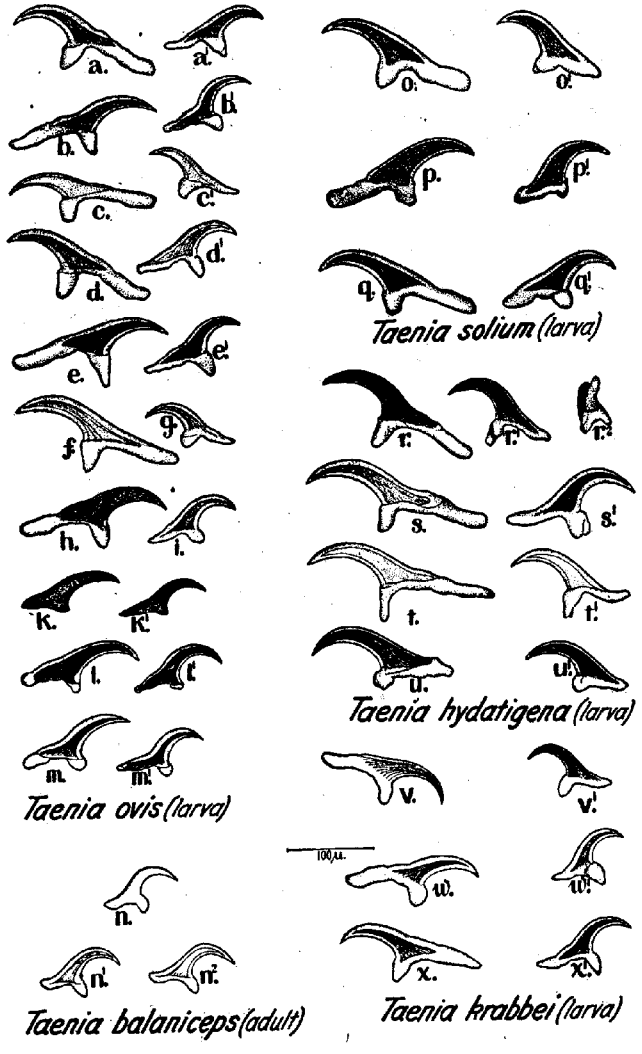

FIG. 6.—Hooks of *Taenia ovis*, *T. hydatigena*, *T. solium*, *T. balaniceps*, and *T. krabbei*. Large and small hooks designated by the same letters are from the same heads. The hooks shown in *v* and *v*¹ are from the type material of *T. krabbei* (B. A. I. No. 19352). Enlarged. (Original.)

antiporal lobe being slightly larger than the other. Laterally the ovary extends to the testicular field, but anteriorly is separated from it by a space which is greatest in

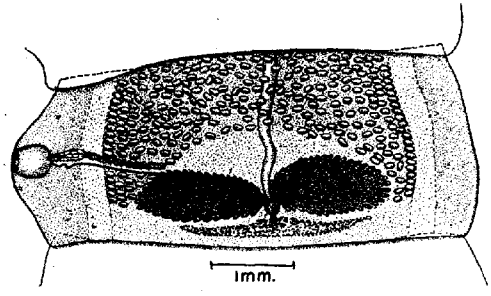

FIG. 7.—Sexually mature segments of *Taenia ovis*. Enlarged. (Original.)

the median line. Posteriorly the testicular field extends beyond the posterior limits of the ovary but slightly, if at all, and falls short of a transverse line drawn through the posterior border of the yolk gland. Gravid uterus (figs. 9 and 10) with 20 to 25 lateral branches from the median stem. Eggs (embryophores) oval, 30 by 24 to 34 by 28μ in diameter.

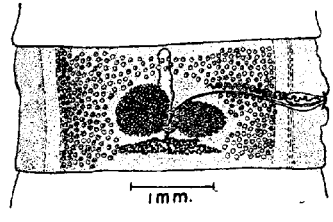

FIG. 8.—Sexually mature segments of *Taenia hydatigena*. Enlarged. (Original.)

HOSTS.—Larval stage: Sheep (*Ovis aries*); goat (*Capra hircus*).[1] Adult stage: Dog (*Canis familiaris*).

LOCATION.—Larval stage: Muscles (heart, voluntary muscles, esophagus), more rarely lungs, wall of stomach (?), and kidneys (?). Adult stage: Lumen of small intestine.

LOCALITIES.—England, France, Germany, Algeria, German Southwest Africa, New Zealand, and United States.

TYPE SPECIMENS.—Probably not in existence.

REMARKS ON MORPHOLOGY AND COMPARISON WITH OTHER SPECIES

The larval stage of the sheep-measle tapeworm somewhat resembles *Cysticercus cellulosae* in its general morphology. The spirally disposed neck and head and the mammillate surface of the caudal bladder suggest the pork cysticercus. The smaller average size and more delicate structure of the cysticercus and the shape and number of the hooks, however, differentiate it quite clearly from *C. cellulosae*. The hooks are somewhat slighter in build, have smaller blades, and are different in outline; the number commonly exceeds the usual number found in *C. cellulosae*, though the limits of variation in number are such in the two forms (24 to 32 in *C. cellulosae*, according to various authors, and 24 to 36 in *C.*

[1] This record is based on a specimen in the collection of the Bureau of Animal Industry collected in April, 1912, from the heart of a goat about 2 years old, origin unknown, slaughtered at one of the abattoirs in Kansas City, Mo.

ovis) that a definite diagnosis can not be made in individual cases on the basis of the number of hooks if this number happens to be 32 or less.

Apart from the fact that its normal location is in muscle and not on serous membranes, *Cysticercus ovis* may be distinguished from *C. tenuicollis* by its smaller size, the different relationship of the head and neck

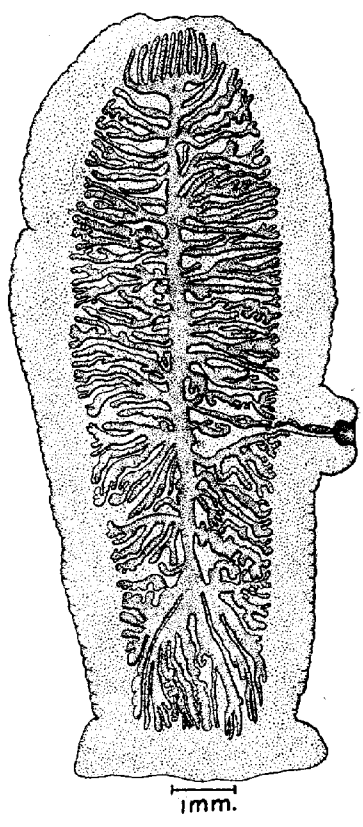

FIG. 9.—Gravid segments of *Taenia ovis*. Enlarged. (Original.)

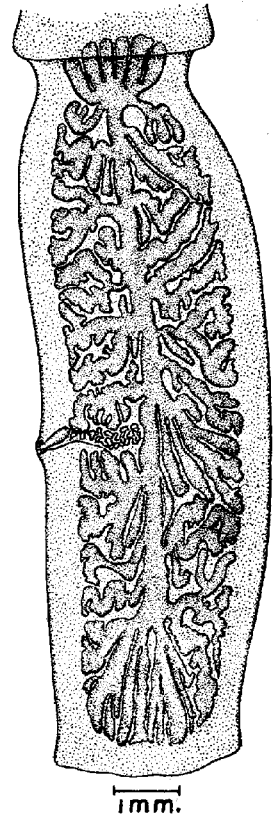

FIG. 10.—Gravid segments of *Taenia hydatigena*. Enlarged. (Original.)

to the caudal bladder, the presence of mammillate projections on the surface of the caudal bladder instead of transverse corrugations, and the different size of the hooks. In *C. tenuicollis* the head and neck are invaginated from one end of the caudal bladder instead of from the side, as in *C. ovis* (Pl. II, figs. 1 and 5). The mammillate projections on the surface of the caudal bladder of *C. ovis* (figs. 5 and 11) are very much in

contrast to the transverse rugæ on the caudal bladder of *C. tenuicollis* (fig..12).

As the number of hooks of *Cysticercus tenuicollis* has been found by various observers to vary from 26 to 44, an accurate distinction between this form and *C. ovis* which would be applicable in all cases can not be drawn on the basis of the number of hooks, though, as a rule, the number of hooks found in *C. ovis* is less than the number commonly present in *C. tenuicollis*. There is also an overlapping in the size of the hooks, the recorded limits for the large hooks being 170 to 220μ in *C. tenuicollis* (larva and adult) and 156 to 188μ in *C. ovis* (larva and adult), and for the small hooks 110 to 160μ in *C. tenuicollis* (larva and adult) and 96 to 128μ in *C. ovis* (larva and adult).

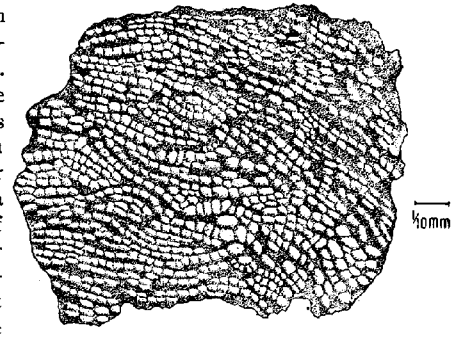

FIG. 11.—Surface of caudal bladder of *Cysticercus ovis* showing papillæ. Enlarged. (Original.)

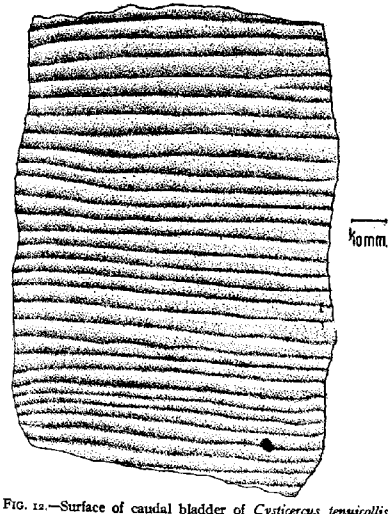

FIG. 12.—Surface of caudal bladder of *Cysticercus tenuicollis* showing transverse furrows. Enlarged. (Original.)

The hooks of *Cysticercus tenuicollis*, however, average considerably larger than those of *C. ovis*, both in total length and in length of blade (fig. 6). In 25 large hooks from four adult and two larval individuals of *Taenia hydatigena* (*C. tenuicollis*) ranging in length from 180 to 212μ, averaging 197μ, the blade varied from 72 to 108μ in length and averaged 93μ; and 20 small hooks from the same specimens ranging in length from 116 to 136μ, average 129μ, had blades ranging in length from 60 to 76μ, average 68μ. The average length of 37 large hooks of *T. ovis* (adult and larva) having a range of 156 to 188μ was 173μ, with the blade ranging from 68 to 84μ,

average 78μ. The average length of 36 small hooks of *T. ovis* (adult and larva) having a range of 96 to 128μ was 113μ, with the blade ranging from 48 to 60μ, average 57μ. In form the hooks of *T. hydatigena* and *T. ovis* are very similar. The small hooks may be distinguished from each other by the fact that the ventral root, though transversely enlarged in both species, is rather deeply bifid in *T. hydatigena* (fig. 6, r^2), a condition which is absent in *T. ovis* or at most only faintly indicated.

Of the more common tapeworms of the dog the one with which *Taenia ovis* seems most likely to be confused is *T. hydatigena* (*T. marginata*), the adult of *Cysticercus tenuicollis*. Apart from the differences exhibited by the hooks as noted above, the segments of the strobila show certain characters by which the two species may be differentiated. (Pl. II, figs. 3, 4, 5; and text fig. 6.) The strobila of *T. hydatigena* is thicker (dorso-ventrally) relatively to its other dimensions than that of *T. ovis* and the latter has a tendency to twist spirally. The segments of *T. hydatigena* have a rather regular quadrilateral form, and the edge of the strobila is comparatively straight, whereas in *T. ovis* the segments have convex lateral borders, the convexity usually being well marked, and the edge of the strobila presents a scalloped outline. The posterior margin of the segment projects more prominently in the former than in the latter species. In *T. ovis* the genital pore is in a large prominent genital papilla, and there is a large and deep genital sinus; in *T. hydatigena* the genital papilla is small and the genital sinus shallow and inconspicuous. The testicles in *T. ovis* do not extend posterior of a line drawn through the anterior border of the yolk gland parallel with the posterior border of the segment; in *T. hydatigena* they extend beyond the posterior limits of the ovary and yolk gland practically to the posterior border of the segment (figs. 7 and 8). With respect to the branching of the uterus, *T. ovis* and *T. hydatigena* are quite different, the uterus of the former having 20 to 25 lateral branches from each side of the median stem, whereas the uterus of the latter has but 5 to 8 such branches (figs. 9 and 10).

Other well-known tapeworms of the dog, such as *Taenia pisiformis* (*T. serrata*), *Multiceps multiceps* (*T. coenurus*), *Multiceps serialis* (*T. serialis*), *Echinococcus granulosus* (*T. echinococcus*), and *Dipylidium caninum*, are less likely than *T. hydatigena* to be confused with *T. ovis*. In addition to distinct morphological differences, the small size of *E. granulosus* and *D. caninum* precludes any chance of mistaking them for *T. ovis*. *T. pisiformis* may be distinguished by the large size of its hooks (the large hooks being 225μ or more in length) and the small number of lateral branches of the uterus (8 to 10). *M. serialis* may be distinguished from *T. ovis* by the fact that the hooks are considerably smaller, the recorded limits of length of the large hooks being 135μ and 157μ, that the ventral roots of the small hooks are distinctly bifid, and that the genital papillæ are small and inconspicuous. *M. multiceps* has large hooks about the same in length as those of *T. ovis* but with blades longer

than half the total length of the hook; and as the genital sinus and genital papilla are very small, the two species may be readily distinguished from each other.

Of the less common or less known tapeworms of the dog the species of *Dibothriocephalus* and *Mesocestoides* are immediately to be distinguished from *Taenia ovis* by the absence of cephalic hooks and rostellum and by the location of the genital pores in the ventral median line of the segment. Likewise, the absence of hooks and rostellum distinguishes *Ophidiotaenia punica* (*Proteocephalus punicus*)[1] from *T. ovis*.

The remaining species of tapeworms known to occur in the dog are *Taenia balaniceps*, *T. brauni*, *T. brachysoma*, and *T. krabbei*, all of which, with the exception of the last, may be readily distinguished from *T. ovis* upon the basis of their published descriptions.

Taenia balaniceps Hall (1910, pp. 139–151, figs. 1–8) differs from *T. ovis* in various particulars, among which may be mentioned the following: The worm is smaller, the length of the longest specimen being only 24 cm.; the head is smaller, not exceeding 752μ in breadth, and the segments in corresponding stages of development are smaller. The hooks are smaller, 93 to 98μ being given as the limits of length of the small hooks and 145μ as the length of the large hooks (fig. 2.) The testicles extend practically to the posterior border of the segment, as in *T. hydatigena*. The lateral branches of the uterus, instead of being slender and more or less separated by intervening spaces as in *T. ovis*, are comparatively thick and are pressed close together.

Taenia brauni Setti, 1897 (Setti, 1897b, pp. 210–214, pl. 8, figs. 9–14), differs from *T. ovis* in that it is much smaller, its total length being from 15 to 18 cm., and the size of the posterior segments 5 or 6 mm. long by 3.5 mm. wide. *T. brauni* was described as lacking a true rostellum but as possessing a double crown of 30 hooks, the large hooks measuring 130 to 140μ, though in some cases only 95 to 100μ in length, and the small hooks usually 85 to 90μ, occasionally 70 to 75μ, in length. *T. ovis*, however, has a well-developed rostellum and hooks considerably larger than the dimensions given for *T. brauni* and is thus clearly a different species from the latter, though the two forms agree in possessing prominent genital papillæ and perhaps are similar in regard to the branches of the uterus, as Setti states that the lateral branches are numerous, slender, and perpendicular to the medium stem.

Taenia brachysoma Setti, 1899 (Setti, 1899c, pp. 11–20, pl. 1, figs. 1–9), is also a much smaller species than *T. ovis*, specimens with gravid segments being not over 10 cm. long and not over 3 mm. in maximum width. The number of hooks is 30 to 32. The large hooks measure 135 to 145μ and the small hooks 95 to 105μ in length, the former thus being considerably smaller than in *T. ovis*, and the latter averaging smaller. The ventral roots of the small hooks are described as having a median groove, thus presenting a condition intermediate between simple and

[1] This species, as pointed out by Hall (1910, p. 146), is probably not a true parasite of the dog.

bifid, at the same time twisted so that the lateral axis tends to lie in the plane of the blade and dorsal root.[1]

The genital papillæ are small and inconspicuous in *T. brachysoma* and the genital sinus measures not over 170μ in maximum depth. The lateral branches of the uterus number only 10 to 12 on each side of the median stem.

Taenia krabbei Moniez (1879c, pp. 161–163; 1880a, pp. 44–50, 56, pl. 1, figs. 12–14, pl. 2, figs. 4–7) produced in a dog by feeding cysticerci from the muscles of reindeer is described as much longer, wider, and thicker than *T. coenurus* and *T. serrata* and has much wider segments proportional to their length, but its head is more delicate. It is also much larger than *T. marginata*, the head is larger, and the segments are wider in proportion to their length. The genital pores are located in large papillæ, often attaining a diameter of 1 millimeter, equal to the length of the contracted segment. The cysticercus according to Moniez is much smaller than the cysticercus of *T. solium*. The number of hooks varies from 26 to 34. The caudal vesicle, compared to the size of the head and neck, is very slightly developed and does not contain much fluid. The orifice of invagination of the cysticercus may be either at one pole or at one side. The invaginated head and neck commonly curve spirally as in *Cysticercus cellulosae*, but to a less degree. The size of the hooks is not given by Moniez.

If the stated magnification of a drawing by Moniez is correct, the length of the large and small hooks would be about 215μ and 160μ, respectively, but inasmuch as the large hooks of *C. tenuicollis*, shown in another drawing, measure, according to the magnification given, about 350μ in length, whereas the maximum recorded length is less than 250μ, it is not unlikely that there has been some error also in stating the magnification of the drawing of the hooks of *T. krabbei*, so that sizes calculated from the magnifications of Moniez's drawings can not be considered at all accurate. Cysticerci in the Bureau of Animal Industry Helminthological Collection found in reindeer in Alaska by Dr. D. S. Neuman and corresponding to *T. krabbei*, so far as may be determined from Moniez's description and figures, except as to the size of the hooks, have hooks (fig. 6) of the following dimensions: Large hooks 150 to 170μ in length, average 162μ, with blades 75 to 80μ long, average 77μ; small hooks 85 to 120μ in length, average 107μ, with blades 52 to 60μ long, average 57μ (measurements based on 34 large and 34 small hooks from 8 cysticerci). The average size of the hooks is thus less than the average of the hooks in *C. ovis*, but they show no remarkable difference in form from those of the latter. Corresponding closely to Moniez's findings, the number counted on eight heads varied from 26 to 32. The invaginated head and neck of the cysticercus form a much larger structure than in *C. ovis* both actually and relatively to the size of the caudal bladder. On account of

[1] Setti does not make it clear whether this twisted condition is invariably present. The small hooks of *Taenia hydatigena* commonly present a similar appearance after subjection to the pressure of a cover glass.

their shriveled condition the size of the cysticerci could not be accurately determined; apparently, however, they are somewhat smaller than *C. cellulosae*, rather slender and considerably elongated. The cysticercus of *T. krabbei* is readily distinguished from *C. ovis* by its elongated form, by the fact that the orifice of invagination of the head and neck is commonly at one end of the cysticercus instead of at the side, and by the larger size of the body formed by the invaginated head and neck both actual and relatively to the size of the caudal bladder. On account of certain evident similarities, such as the prominent genital papillæ, and on account of the lack of an accurate detailed description of *T. krabbei*, no clear distinctions can be drawn between *T. krabbei* and *T. ovis*, though, no doubt, distinct differences could be found upon comparing specimens of the two species.

Since the foregoing paragraph was written some of Moniez's cotypes have been received from Prof. R. Blanchard, one specimen of the adult (B. A. I. No. 17351) and two specimens of the cysticercus (B. A. I. No. 17352). The cysticerci, considerably shrunken, measure about 2 by 3 mm. The surface of the caudal bladder is mammillated (as is also the case in the Alaskan cysticercus), and the cysticercus in this character thus resembles *Cysticercus ovis*. The number of hooks was not determined, as most of them in the one specimen dissected were lost in mounting. Two of the large hooks measured 148μ in length and had blades 70μ long. A small hook measured 105μ in length and had a blade 60μ long (fig. 6, *v*, *v'*). It has thus been determined that the sizes heretofore assigned to the hooks of *Taenia krabbei*, based on Moniez's drawings, are erroneous and the apparent discrepancy between *T. krabbei* and the Alaskan cysticercus, noted in the preceding paragraph, has been removed. The ventral root of the small hooks is transversely enlarged, but is not distinctly bifid. A tendency toward the bifid condition, however, has been observed in some instances in the Alaskan specimens. The data thus far available do not indicate a specific difference between Moniez's species and the Alaskan form, and the weight of evidence is still in favor of the correctness of the presumption that the Alaskan cysticercus and *T. krabbei* are identical. The adult specimen (B. A. I. No. 17351) corresponds closely to the drawing given by Moniez (1880a). The segments are remarkable for their great breadth, as compared with their length, and the large genital papillæ, about a millimeter in diameter, are quite conspicuous. As the strobila may be abnormally contracted in length, too much weight should not, perhaps, be placed upon the extreme shortness of the segments relative to their width as a feature by which *T. krabbei* may be distinguished from *T. ovis*. It seems probable, however, that there is a more or less marked difference in this respect between the two forms. The two posterior segments in the specimen of *T. krabbei*, which are gravid, are nearly as long as broad, measuring about 4 mm. in length by 4.5 mm. in breadth. They are considerably smaller than the gravid segments of *T. ovis*. A distinct difference

between *T. ovis* and *T. krabbei* is apparent in the gravid uterus. Instead of the 20 to 30 lateral branches seen in *T. ovis* there are in *T. krabbei* only about 10 lateral branches from each side of the median stem. It is quite clear from the brief study which has been made of the type material of *T. krabbei* that it is specifically distinct from *T. ovis*, although the similarity between the two species is very close in many respects.

MACROSCOPIC APPEARANCE OF CYSTICERCUS OVIS

The cyst of the fully developed undegenerated cysticercus as seen embedded in the muscles of its host is oval and varies in size from 4 by 2.5 mm. to 9 by 4 mm. or slightly larger (Pl. III, *A* and *B*). It is whitish in color and varies in transparency according to the thickness of its fibrous capsule, which may be very thin and rather transparent or comparatively thick and rather opaque. In transparent cysts the head and neck of the cysticercus are apparent as a small, bright, white spot showing through the wall of the cyst. Removed from its cyst the cysticercus (Pl. II, fig. 1) appears as a small oval vesicle very transparent and delicate, filled with a clear fluid, and varying in size when fully developed from 3.5 by 2 mm. to 9 by 4 mm. On one side may be seen the opaque white head and neck invaginated into the vesicle or quite commonly partially evaginated and then projecting above the surface of the vesicle. *Cysticercus ovis* is more delicate in appearance and averages in size smaller than *C. cellulosae*. It is considerably smaller than a fully developed *C. tenuicollis*.

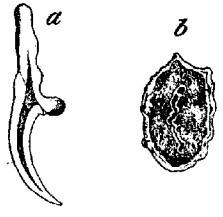

FIG. 13.—*Cysticercus oviparians* (= *C. Ovis*): *a*, Hook, ×160; *b*, cyst containing cysticercus cut across, ×2. (After Maddox, 1873a, pl. 18 fig. 1.)

Degenerate cysts (fig. 13, *b*, and Pls. III, fig. *E*, and IV, fig. 2) vary in size, shape, thickness of capsule, and consistency and color of contents. The sizes of 50 degenerate cysts taken at random varied from 3.5 to 15 mm. in diameter; 7 by 4 mm. was a common size. Different authors have observed cysts varying in size from that of a millet seed to that of a bean. The shape is commonly oval or spheroidal, but may exhibit various irregularities.

The fibrous capsule of the degenerate cyst may be quite thin or relatively very thick. For example, the capsule of a cyst from the masseter muscle, measuring 7 by 4 mm., was about one-third of a millimeter thick; another cyst, 5 by 2.5 mm. in diameter, from the same muscle had a capsule about three-fourths of a millimeter thick; a cyst 10 by 7 mm. from the heart had a capsule 3 mm. thick; and the capsule of another cyst, 8 by 6 mm. in diameter, also from the heart, measured one-third of a millimeter in thickness. The cavity of the cyst is commonly irregular in shape and contains besides the cysticercus a mass of caseous, caseo-calcareous, or calcareous material, or sometimes an albuminous coagulum or a soft purulent substance. The color of the contents may be white, yellowish,

greenish, orange, or brown, and several of these colors may be observed in the contents of a single cyst. In some cases the cysticercus more or less shriveled and commonly with evaginated head may be readily distinguished upon close scrutiny, but generally is to be found only with difficulty in degenerate cysts. The dead cysticercus found in degenerate cysts usually has a bright-white color which makes it more readily apparent when the contents of the cyst happen to be mostly of a contrasting color. In some of the larger degenerate cysts it is noteworthy that the cysticerci found have been no larger than those found in much smaller cysts. For example, the cysticerci found in two degenerate cysts, 10 by 9 and 10 by 7 mm. in diameter, respectively, measured in their shriveled condition 2 mm. in diameter in one case and 2½ mm. in diameter in the other and thus were somewhat smaller than the shriveled cysticercus from a cyst 5 by 4 mm. in diameter, which measured 3 by 2 mm.

DISTRIBUTION IN BODY

The cysts of *Cysticercus ovis* as found in sheep carcasses are usually comparatively few in number and are commonly limited to the heart or diaphragm, though in many such cases if the muscular parts of the carcass are cut into slices additional cysts are brought to view. Not uncommonly cysts may be found in the muscles of mastication and in the tongue. Sometimes they appear superficially on the muscles beneath the skin, sometimes in the panniculus carnosus itself. The abdominal musculature is not uncommonly affected. Degenerate cysts may be found in the lungs, and in this location they can not be distinguished macroscopically from the small degenerate cysts of *C. tenuicollis*. The parasites have been found in a degenerate condition in the wall of the esophagus. Degenerate cysts found in the wall of the rumen and fourth stomach in a lamb which had been fed segments of tapeworm (pp. 23 and 24) were propably *C. ovis*. Morot has found degenerate cysts in the kidney which may have been *C. ovis*. Degenerate cysticerci in the liver are probably not *C. ovis*, but are more likely *C. tenuicollis*, which frequently occurs in this location. In the writer's experiments none of several lambs fed segments of the tapeworm stage of *C. ovis* showed any invasion of the liver, whereas the liver was affected in each of two lambs fed segments of *Taenia hydatigena*.

Cysticercus ovis is therefore essentially a parasite of the intermuscular connective tissue and occurs but rarely in other locations. Except the heart and diaphragm, the parasite appears to have no distinct preference for any particular location in the carcass, and the parts named may appear to be preferred by the parasite simply because these parts are the most readily examined in post-mortem inspection, so that carcasses which have these parts affected are likely to be picked out by inspection, whereas other carcasses which may harbor cysts somewhere in the depths of the musculature are passed by because they show no cysts in accessible parts. The muscles of the head, particularly the muscles of mastication, are

frequently the seat of infestation, and these muscles may be considered as perhaps a preferred location, though this is uncertain. That the tongue is a common location has been established by Dr. W. J. Stewart of the Bureau of Animal Industry, who has found that about one-half of 1 per cent of the tongues of all sheep slaughtered at his station are infested.

LOCATION IN SHEEP CARCASSES EXAMINED IN UNITED STATES

In the cases given in Table I the carcasses were examined by slicing the musculature. The number of cysts found in various locations is given. The number found in the head in some instances includes cysts found in the tongue. The columns designated "Superficial" and "Deep" refer, respectively, to cysts elsewhere than in the heart, diaphragm, and head which were either found on a superficial examination of the dressed carcass (Superficial) or were embedded in muscle so that they were found only on dissection (Deep). Cases Nos. 1 to 6 were examined by Dr. I. C. Mattatall at National Stock Yards, Ill.; Nos. 7 to 12 and 13 to 16 by the writer at Seattle, Wash., and Portland, Oreg., respectively; Nos. 17 and 18 by Dr. R. E. Holm at Wallace, Idaho; No. 19 by Dr. E. C. Joss at Tacoma, Wash.; Nos. 20 to 25 by Dr. E. C. Joss at Seattle, Wash.; Nos. 26 to 32 by Dr. E. C. Joss at Portland, Oreg.; Nos. 33 to 35 by the writer at Chicago, Ill.; Nos. 36 to 38 by Dr. I. C. Mattatall at National Stock Yards, Ill.; and No. 39 is lamb No. 1 in the experiments already reported in this article (pp. 23 and 24).

TABLE I.—*Location of Cysticercus ovis in sheep carcasses examined after dissection.*

Case No.	Location of cysts.					Case No.	Location of cysts.				
	Heart.	Diaphragm.	Head.	Superficial.	Deep.		Heart.	Diaphragm.	Head.	Superficial.	Deep.
1	1	.....	1	.....	9	21	1 or 2	.....	.....	.....	7
2	1	.....	1	.....	.....	22	1	.....	.....	.....	.....
3	.....	1	1	.....	.....	23	1 or 2	.....	.....	.....	.....
4	2	2	1	.....	8	24	1 or 2	.....	.....	.....	.....
5	4	1	1	.....	3	25	1	.....	.....	.....	5
6	14	1	9	.....	30	26	1	1	.....	.....	2
7	.....	1	.....	.....	.....	27	1	.....	.....	2	.....
8	.....	.....	.....	1	.....	28	.....	.....	.....	3	10
9	.....	1	.....	.....	.....	29	2	1	.....	.....	3
10	.....	1	.....	.....	.....	30	.....	1	1	.....	1
11	.....	1	.....	.....	.....	31	1	.....	1	.....	1
12	.....	.....	.....	1	.....	32	1	.....	.....	1	.....
13	1	.....	.....	.....	3	33	1 or more.	.....	2	1	7
14	1	.....	.....	.....	3						
15	2	.....	.....	.....	.....	34	18	15	27	2	X[1]
16	.....	1	.....	.....	6	35	3	3	3	.....	35
17	1	1	.....	.....	.....	36	2	.....	1	.....	.....
18	.....	.....	1	.....	.....	37	1	.....	.....	1	1
19	.....	.....	.....	2	1	38	1	.....	1	1	3
20	1 or 2	.....	.....	.....	10	39[2]	X[1]	42	X[1]	X[1]	X[1]

[1] X indicates numerous cysts.

[2] This carcass also had degenerate *Cysticercus ovis* in the lungs and wall of esophagus and degenerate cysts in the wall of the rumen and fourth stomach which were probably *C. ovis*.

A carcass examined by Dr. O. B. Hess at Seattle, Wash., not recorded above, showed 1 cyst in the heart, 3 in the masseter muscles, 15 in the forequarters, 22 in the "rack," 13 in the saddle, and 7 in one hind leg. The number in the diaphragm or visible superficially was not stated.

Besides the carcasses referred to above there were examined in Chicago in April, 1912, by Dr. W. C. Siegmund and the writer, 59 carcasses which had been retained in the course of routine inspection on account of the presence of cyst in the heart. The examination consisted in examining carefully the diaphragm and the surface of other exposed muscles, examining the internal and external muscles of mastication and tongue after slicing them, and finally examining the cut surfaces after the carcass had been cut into three to five market cuts.

Four carcasses for which the number of cysts in the heart was not recorded showed no additional cysts. Fifty carcasses had one cyst in the heart. Ten of these had additional cysts, three having one cyst each in the diaphragm, two having one and two cysts, respectively, in the muscles of mastication, two having one superficial cyst each in the abdominal musculature and on the hind leg just below the patella, respectively, three having one cyst each on the cut surface of a hind quarter, "rack," and forequarter, respectively, and one having a cyst in the wall of the esophagus. Three carcasses which had two cysts in the heart showed no additional cysts. Two carcasses which had three cysts in the heart showed no additional cysts.

DEGENERATION OF CYSTICERCUS OVIS

The cysticerci observed in the course of the routine post-mortem inspection of sheep are usually more or less degenerated, and are either in a condition of caseation or calcification (Pls. III, fig. *E*, and IV, fig. 1). This does not necessarily indicate that live cysticerci are relatively rare. It may be accounted for in part by the fact that degenerate cysticerci are much more conspicuous than the live parasites and, hence, less likely to be overlooked. On the other hand, the validity of this explanation is somewhat offset by the possibility that the cysticerci remain alive only for a short period compared with the length of time they persist in the degenerated condition, in which event one would expect to find degenerated cysticerci more often than living ones. How soon degeneration may begin or how rapidly it may proceed is uncertain, but it is quite clear that in different instances the process varies considerably in these respects and in its character as well. Degeneration as noted elsewhere may occur before the cysticerci have reached their full development. It is probably often influenced by the presence of bacteria introduced by the parasite itself or carried to the cyst by the blood stream, and bacterial action may perhaps have a great deal to do with the large size commonly attained by the degenerate cysts of *Cysticercus ovis*.

The results of the experiments described in another part of this paper prove that degeneration may begin in less than three months after infection, but no data are at hand to show how soon the process may be completed; nor, on the other hand, is it known how long the cysticercus may remain in the tissues of its host before it dies and degenerates.

The various degenerative processes occurring in *Cysticercus ovis* have not been worked out in detail and, hence, will not be considered at length. They are quite similar, at least in some of their variations, to the processes of degeneration which affect *C. bovis* and *C. cellulosae*. A very common occurrence in the case of *C. ovis*, as already alluded to, which seems to be quite unusual in the case of the other two species, is the tendency of degenerate cysts to reach a size which is very large in comparison with the cysticercus itself. In some instances it appears that the increase in size of the cyst may go on indefinitely, fresh calcareous material being continually deposited in the cyst, associated with a breaking down of the inner layers of the capsule and a new growth peripherally.

Like the beef cysticercus, *Cysticercus ovis* tends to degenerate comparatively early when located in the heart. For example, the cysts in the heart of a lamb killed 83 days after infestation (p. 24), so far as observed, were all degenerate. Some of the cysticerci in other locations, including the muscles of mastication, were degenerate, but the great majority were alive. Except in the case of the heart, no definite relation has been observed between the location of the cysticerci and the liability to early degeneration.

The association of live and degenerate cysticerci in the same carcass is a matter of interest, though of less practical importance than in the case of beef and pork measles. In beef measles the association of live and degenerate cysticerci in the same carcass is fairly common. It is often stated in regard to *Cysticercus cellulosae* that if any of the parasites in an infested carcass are degenerated it is likely that all of those present will also be in the same condition. This is by no means invariably true. In a case of pork measles seen by the writer in October, 1912, at an abattoir in Chicago, most of the cysticerci were undegenerated, but degenerate cysticerci were quite common, particularly in the diaphragm and superficial muscles. In the case of *C. ovis*, so far as the writer's experience goes, if the cysticerci found in the heart, diaphragm, muscles of mastication, and other parts of the carcass readily accessible for examination are degenerated, the cysticerci in other parts of the body are likewise, as a rule, in a similar condition. Nevertheless, if *C. ovis* were transmissible to man, it would be unsafe, when only degenerated cysts are found on inspection, to pass a carcass for food upon the assumption that any that might be present in uninspected portions of the musculature would also be degenerated. Live and degenerated cysticerci occasionally, at least, occur together in the same carcass. As noted

above, a considerable number of degenerated cysticerci were found in a sheep 83 days after infection, though most of the parasites were still alive and undegenerated. One other case is recalled in which degenerated and living cysticerci were associated. In this case the cysticerci in the heart, diaphragm, and muscles of mastication were degenerated and partially calcified, as were several found in various portions of the body musculature, but deep in the muscles of one hind leg there was a live cysticercus showing no signs of degeneration whatever.

This accords with what would naturally be expected. One would expect live and degenerate cysticerci in the same carcass as the result, first, of variations in the longevity of cysticerci, as in the case of the experimental sheep mentioned above, or, second, as the result of infestations occurring at different times. It seems that the latter must surely occur often. In view of the close association which commonly exists between sheep and dogs, the sheep in a flock attended by an infested dog are exposed to the chance of repeated infestation, and, hence, sheep must frequently harbor simultaneously cysticerci which have come from eggs ingested on various occasions.

DIAGNOSIS OF SHEEP MEASLES

So far as known, the presence of *Cysticercus ovis* can not ordinarily be determined in the living animal, and its diagnosis therefore depends upon a post-mortem examination. It is not always possible to determine definitely whether cysticerci found in sheep or goats are or are not *C. ovis* without resorting to the use of the microscope, but usually microscopic examination is not necessary.

The location of *Cysticercus ovis* in muscle tissue differentiates it clearly from *C. tenuicollis,* which, so far as has yet been proved, is found only in relation with serous membranes. Cases occur, however, in which this rule can not be applied with certainty, as, for example, when the diaphragm or abdominal muscles are involved it is sometimes practically impossible to state on the basis of location alone whether the parasite in question is *C. ovis* or *C. tenuicollis*—that is, the parasite may appear to be in direct relation both with the musculature and the serous membrane which covers the musculature. Here the size of the cysticercus may help to determine its identity; if over 10 mm. (two-fifths of an inch) in diameter, it is *C. tenuicollis;* if less than this size, it is probably *C. ovis,* but may be a young *C. tenuicollis.*

The relation of the head to the caudal bladder—midway between the two ends in *Cysticercus ovis* (Pl. II, fig. 1) and at one end (Pl. II, fig. 5) in *C. tenuicollis*—will indicate the species if the parasite happens to be of a well-marked oval form. Even in very young cysticerci in which the head is yet rudimentary, the relative position of the head is the same as in the fully formed cysticercus. Cysticerci affecting the liver of sheep or

goats may be assumed to be *C. tenuicollis*. *C. ovis* has not as yet been found in the liver. Even in carcasses exhibiting heavy infestation of the musculature, the liver has not been involved. Small-sized cysticerci in the lungs, however, may be *C. ovis*, as degenerate cysticerci of this species have been found in this location in a case of heavy infestation of the carcass.

More difficulty is likely to be experienced in the identification of degenerate cysticerci than of the live parasites, and even more than in the case of the live cysticerci the location must be chiefly depended upon in distinguishing macroscopically between *Cysticercus ovis* and *C. tenuicollis*.

The cysticercal nature of degenerate cysts can often be confirmed by squeezing out the cysticercus, or fragments of it. It should be remembered that the degenerate cyst may be of a much larger size than the contained cysticercus, so that the fact that a cyst is larger than the maximum size of *Cysticercus ovis* does not necessarily exclude this species from consideration. Degenerate cysts of *C. tenuicollis* on the diaphragm or abdominal muscles commonly become more firmly calcified than those of *C. ovis* and show a white, wrinkled surface not seen in the case of the latter.

Excluding from consideration cases of invasion of the musculature by the gid bladder worm, whose true nature will be revealed by examination of the brain and the discovery of characteristic lesions in that location there are two known conditions which may be mistaken for the degenerate cysts of *Cysticercus ovis:* Namely, large *Sarcocystis* nodules and encysted foreign bodies, such as barbs from certain plants which work through the tissues and finally come to rest somewhere in the muscles and become encysted.

In the case of *Sarcocystis* nodules shown in the accompanying illustration (Pl. III, figs. *C* and *D*) there were a considerable number of nodules in the diaphragm and heart, 5 mm. and upward in diameter. The walls of these cysts were firm and thick, their contents of a purulent nature. No cysticerci or remains of cysticerci could be discovered. Instead, in each cyst there were found one or more small, transparent vesicles not visible except microscopically. These vesicles, with delicate membranous walls of homogeneous structure without nuclei, contained a finely granular substance and numerous calciform spores about 15μ long, which demonstrated conclusively that the cysts were *Sarcocystis* cysts. Usually *Sarcocystis* cysts in sheep are so small as to be evident only microscopically, and cysts large enough to be seen with the naked eye are, so far as known, very rare. Knowledge of the characteristics of the unusual forms of *Sarcocystis* cysts such as that described above is too limited to enable one to state definitely the points by which they may be differentiated macroscopically from degenerate *Cysticercus ovis* cysts. In

the case of the latter, however, it is frequently possible by opening the cyst and squeezing out its contents to demonstrate the presence of a cysticercus or the visible and recognizable fragments of one. *Sarcocystis* cysts simulating degenerate *C. ovis* cysts are, so far as appears from our present knowledge, of rare occurrence, and consequently cysts occurring in the musculature of the size and general appearance of degenerate *C. ovis* are presumably *C. ovis* unless there is evidence to show that they are not, such as, for example, the discovery of *Sarcocystis* spores and the total absence of any cysticercus or remnant thereof.

Illustrating the possibility of confusing encysted plant barbules with degenerate *Cysticercus ovis* cysts is a case recently observed in which there was a small nodule about 5 by 4 mm. in diameter in the diaphragm in the muscle tissue just beneath the serosa. This nodule consisted of a thin capsule and contents of a somewhat caseous consistency and might have been taken on casual observation for a small degenerate *C. ovis* cyst. Careful examination, however, failed to reveal any morphological evidence of a cysticercus, instead of which there were found in the midst of the caseous material three or four tiny barbules from some plant, very finely pointed and tapering and spirally coiled. These were scarcely evident to the unaided eye amid the cascous material, but their nature became quite apparent on microscopic examination.

GEOGRAPHIC DISTRIBUTION

Abroad, cases of sheep measles have been found in England, France, Germany, Algeria, German Southwest Africa, and New Zealand.

In this country relatively few of the numerous cases found at abattoirs have been traced to the point of origin of the infested sheep. Cases traced to the point of origin have been from Montana (10 counties [1]), Idaho (5 counties [2]), Washington (4 counties [3]), Oregon (11 counties [4]), California (3 counties [5]), Colorado (1 county [6]), and Nevada (middle and western part).

The parasite is probably more or less generally distributed throughout the western United States, and is likely present also in the East, though as yet no cases have been definitely traced to eastern localities. It is probable that it will be found to occur wherever sheep are attended by dogs, particularly wherever dogs have frequent opportunities of devouring dead sheep.

[1] Rosebud, Yellowstone, Meagher, Cascade, Choteau, Hill, Blaine, Lewis and Clark, Teton, and Beaverhead Counties.

[2] Fremont, Bonneville, Bingham, Washington, and Canyon Counties.

[3] Adams, Walla Walla, Yakima, and Klickitat Counties.

[4] Polk, Benton, Marion, Multnomah, Crook, Gilliam, Morrow, Umatilla, Union, Wallowa, and Baker Counties.

[5] Modoc, Tehama, and Butte Counties.

[6] Conejos County.

PREVALENCE

Most of the published records of sheep measles refer to isolated cases found by accident, and accordingly indicate little as to the prevalence of the parasite. Glage (1905), however, in Germany, found degenerate cysticerci in the muscles of 32 out of 2,198 (1.45 per cent) sheep carcasses examined for these parasites by inspection of the head muscles and the heart, and in 16 out of 1,984 (0.8 per cent) in which the heart only was inspected.

Table II shows the total number of sheep slaughtered at 26 meat-inspection stations in the United States during 11 months beginning January, 1912, and the number of carcasses found affected with muscle cysticerci.

TABLE II.—*Carcasses of sheep found affected with muscle cysticerci during 11 months at 26 meat-inspection stations in United States.*

Station.	Total kill.	Affected.		Station.	Total kill.	Affected.	
	Number.	*Number.*	*Per cent.*		*Number.*	*Number.*	*Per cent.*
A	898	1	0.01+	O	31,237	17	0.05+
B	262,361	1	.....	P	6,920	1	.01+
C	4,335,153	4,678	.11−	Q	116,912	564	.48+
D	100,382	34	.....	R	19,708	109	.55+
E	157,053	12	.01−	S	59,759	1	.....
F	61,905	107	.17−	T	23,381	132	.57−
G	55,205	10	.02−	U	161,010	1,469	.91+
H	237,799	2	.....	V	2,106	1	.05−
I	1,488,997	2,695	.18+	W	1,435,594	5,739	.4 −
J	272,739	35	.02−	X	526,713	30	.01−
K	36,976	23	.06+	Y	166,581	19	.01+
L	706,584	1,010	.15−	Z	86,238	741	.85−
M	91,784	1	.....				
N	1,429,264	14	.....	Total	11,601,898	17,446	.15+

The foregoing table does not indicate accurately the prevalence of sheep measles. In the first place, many cases would necessarily be missed under methods of inspection as nearly perfect as practically possible; in the second place, the methods of inspection for *Cysticercus ovis* have not been developed to the same degree of perfection at the various stations; and finally, at certain stations the methods of inspection for *C. ovis* have reached a high degree of efficiency only in recent months, while the figures given cover also earlier months during which the inspection was less perfect and during which it may even have happened that no cases were found at all. For example, it will be noted from Table II that, in the case of Station R, 0.55 per cent of the sheep slaughtered during January to November were found to be infested. As a matter of fact, however, the great majority of the cases of measles at the station were found toward the close of the period covered; that is, 105 cases, or 2.25 per cent of about 4,300 sheep slaughtered, were found during September, October, and November.

The actual percentage of sheep infested with measles, at least in those sections of this country where a close relationship exists between sheep and dogs, probably approximates 5 per cent much more nearly than it does the very small percentage derived from the figures given in Table II.

AGE OF INFESTED SHEEP

Information as to the age at which sheep are most likely to be found infested with measles is meager. A priori it would be expected that rather young animals would most commonly show infestation. As a rule, young animals are more liable to infestation with tissue parasites than old animals, possibly because their tissues offer less resistance to the migration of the parasites than those of older animals. This greater susceptibility is offset to some extent by the fact that the longer an animal lives the more opportunity he has for becoming infested, other things being equal.

Among a total of 189 infested sheep whose ages (approximate) were recorded by inspectors of the Bureau of Animal Industry at several stations, the distribution of cases according to age was as follows:

	Number of cases.		Number of cases.
6 months	20	2 to 4 years	12
8 months	57	3 to 5 years	14
10 months	3	4 years	1
1 year	4	5 years	10
1½ years	3	6 years	2
2 years	63		

Owing to the lack of data as to the relative numbers of sheep of these various ages which are slaughtered, the figures in the above table do not prove anything. They seem to indicate, however, that *Cysticercus ovis* is more commonly met with in young than in old sheep. As one possible explanation of the apparent rarity of *C. ovis* in old sheep it is reasonable to suppose that as the animals grow older any parasites which they may have picked up in earlier life tend to disappear more or less completely as a result of degeneration and absorption by the surrounding tissues. Meanwhile with increasing age the susceptibility to infestation diminishes, and this, combined with the death and disappearance of the parasites acquired during youth, tends to result in freedom from infestation.

ECONOMIC IMPORTANCE

Sheep measles, instead of being as formerly considered a sort of zoological or pathological curiosity, is a matter of great importance to the sheep grower, the butcher, and the consumer of mutton. Although the tapeworm cysts are not transmissible to man, mutton infested with them is not a desirable article of food, and modern ideas in meat inspection require that mutton infested with these parasites to any considerable

extent shall either be condemned or rendered into tallow, according to the degree of infestation, although theoretically there is no objection from the hygienic standpoint to passing affected mutton for food after the parasites have been removed. Practically, however, it is impossible in many cases to remove the parasites, because such extensive dissection would be required that there would be but little left of the meat when the parasites had been removed. Consequently, therefore, a large number of sheep carcasses which are retained by inspectors on account of measles go either to the tallow tank or to the condemned tank, because the character of the infestation is such that it is impracticable to remove the parasites.

At first thought it might seem that the loss on account of these condemnations would fall on the butcher, as the sheep are already bought and paid for before they are passed upon by the meat inspector, but as a matter of fact the producer is made to bear at least a part of the loss. When a condition involving losses on account of condemnations exists among live stock and continues to prevail, the butchers naturally and invariably make ample allowances in the prices paid for the probable loss from condemnations based upon their experience as to losses in the past, so that the producer, although he may not realize it, is made to bear more or less of the burden, sharing it, perhaps, with the consumer, to whom it is likely the butcher will pass on a portion of his loss.

The Federal meat-inspection records, as already noted, indicate that tapeworm cysts in the muscles of sheep are common throughout the West, and furthermore, it is safe to say that the proportionate number of cases of sheep measles found on post-mortem inspection, already representing a high percentage, will continue to increase as meat inspectors become more expert in detecting the presence of the parasites. The natural consequence will be that sooner or later, if this is not already the case, the sheep raiser will suffer a reduction in the selling price of his product below that which he would receive were it not for the losses from condemnations experienced by the butcher.

This indirect loss is in all probability not the only loss experienced by the sheep raiser. It has already been noted that in the experiments five of the lambs died in from 13 to 23 days after infestation. These died approximately in the order of the size of the doses of tapeworm eggs given, those receiving the smallest doses surviving the longest. Three of them received only the eggs contained in a single tapeworm segment, the other two receiving 3 and 10 segments, respectively. The sixth sheep, which survived, received only one-half of a segment, yet the number of eggs was sufficient to make the animal sick for a time, corresponding probably to the period during which the embryonic worms were invading and establishing themselves in the muscles. Quite clearly, therefore, the sheep-measle parasite is deadly in its effects upon sheep, provided a sufficient number of tapeworm eggs are swallowed, and even

if not enough are swallowed to kill the animal, it may be made sick by the invasion of the parasites. Accordingly it is quite probable that many of the cases of death and sickness, which are more or less constantly occurring among sheep without apparent cause, are the result of infestation with the measle parasite.

It has been suggested by Dr. S. W. McClure that sheep measles may be responsible for the many stiff lambs found during spring and summer on the western sheep ranges.

SIGNIFICANCE IN MEAT INSPECTION

As *Cysticercus ovis* affects the very part of the carcass which is the most valuable as food—namely, the musculature—it is of great interest in meat inspection and of special importance on account of its prevalence.

Under a system of meat inspection which recognizes but one class of meats as fit for food, such as the system provided for by Federal law in this country, it is proper to pass for food sheep carcasses which show a slight infestation with *Cysticercus ovis* after the removal of the parasites and any lesions caused by them. Carcasses showing more than a slight infestation may be rendered into edible tallow, but if heavily infested should be condemned. As a rule, packers do not take advantage of the provision which permits moderately infested carcasses to be rendered into tallow, but prefer to treat such carcasses the same as condemned carcasses and to manufacture them into inedible products. Though it is possible that all the parasites may not be found and removed from slightly infested carcasses, since it is manifestly impracticable to inspect the depths of the musculature throughout the carcass, it has been determined by experience that there is little likelihood that more than one or two, if any, cysts will be present in the depths of the muscles if only a few are found in the heart, diaphragm, head muscles, tongue, and other superficial or readily accessible parts. Accordingly, if only a limited number of the parasites are found in these locations, there is no reasonable objection to passing such a carcass after their removal.

Even if carcasses are occasionally passed which contain a few cysts that have escaped observation because hidden in the musculature, no great harm is done, since the parasites are not transmissible to man and at most can only offend the esthetic sense of the consumer. Certainly the consequences of passing such carcasses do not balance the great waste which would result if all sheep carcasses infested in any degree whatsoever (amounting to 1, 2, 3, perhaps even 5, per cent of the total number slaughtered) were excluded from use as food. In the light of our present knowledge the German regulations are unnecessarily stringent in placing sheep measles in the same category as pork measles, the basis of these regulations, of course, being the unproved and apparently altogether false assumption that the parasite concerned is *Cysticercus*

cellulosae, and hence transmissible to man. Under American regulations concerning *Cysticercus cellulosae*, necessarily more stringent than the German regulations because of the absence of a Freibank in our system of handling meats, no sheep carcass affected with measles even in the slightest degree could be passed for food if the sheep parasite were *Cysticercus cellulosae*. The demonstration of the fact that the muscle cysticercus of sheep is not *Cysticercus cellulosae* and that it is not transmissible to man therefore means that many thousands of sheep carcasses which would otherwise go unnecessarily to the tallow or condemned tank are saved for food, and thus fortunately one of the factors involved in diminishing our already too slender meat supply has been eliminated. Even during the year 1912, when the prevalence of sheep measles was first recognized and before the inspection for *Cysticercus ovis* had been developed to an efficient stage, the money value of sheep carcasses retained on account of measles amounted to nearly $100,000.

The person who kills mutton for his own use need not be so critical nor so strict with reference to sheep measles as the official meat inspector. The latter, in the absence of legal provision for a Freibank where meat not dangerous to human health but of inferior grade can be sold, has to exclude a great deal of meat from the market which is fit for food under certain conditions, though it can not properly be passed on the same basis as meat unconditionally fit for food. Home-dressed sheep carcasses, therefore, even though infested in a higher degree than would be permitted in carcasses which may pass for food under the Federal meat-inspection regulations may better be utilized for food than wasted, although here the individual will largely be governed by his own feelings in the matter, by his squeamishness or lack of it. Such carcasses, however, should not be sold, at least not without declaration of their nature, as they are obviously of less value than carcasses which are free from infestation.

So far as its detrimental effect on account of the presence of *Cysticercus ovis* is concerned, measly mutton may be eaten with impunity unless the parasites are very numerous or have produced a watery condition or discoloration of the meat, in which case the carcass should be discarded even though the prospective consumer may have no objections to the meat from an esthetic standpoint. In order that further propagation of the parasites may be avoided, a measly sheep carcass discarded from use as human food should not be fed to dogs unless it is first cut into small pieces not exceeding 2 or 3 pounds each and thoroughly boiled.

SURVIVAL OF CYSTICERCUS OVIS AFTER DEATH OF HOST

The length of time *Cysticercus ovis* may survive after the death of its host has not been determined. It will, however, live at least six days. Cysticerci in portions of a carcass shipped from Chicago on March 25, 1913, presumably the day of slaughter, and received in Washington on

March 28, were still alive on March 31. After its arrival in Washington the meat was kept in an ice box, at a temperature not lower than 40° F.

As to the period of survival when frozen it was found in one experiment that the cysticerci in a sheep slaughtered on October 15, 1912, were dead on November 7, 23 days after slaughter, the mutton meanwhile having been kept in a frozen condition. Through an oversight no examination of the mutton was made at intervening dates, so that no information was obtained as to how long the parasites actually retained their vitality. The cysticerci were observed by Dr. L. E. Day, who took charge of this experiment on November 7, to be slightly shriveled after thawing. On November 7, about half a pound of the infested mutton was fed to a dog and similar amounts on November 8, 9, 10, and 11. On the last date another dog was also fed. Autopsy on the former dog on December 2, 24 days after feeding, showed no parasites of any kind in the alimentary tract. The other dog when examined post-mortem on January 4, 53 days after feeding, showed a few *Dipylidium caninum*, but no other parasites.

From this experiment it appears probable that a period of three weeks is sufficient, as in the case of *Cysticercus bovis*, to insure the death of cysticerci in mutton. Since, however, *Cysticercus ovis* is not transmissible to man, the same necessity of holding slightly affected carcasses in cold storage for a sufficient period of time to destroy the vitality of any cysticerci which may have been overlooked does not exist. In this respect it is accordingly not so important as in the case of *Cysticercus bovis* to know how long the cysticerci may survive after the slaughter of its host.

PROPHYLAXIS

In addition to the highly important preventive measure of destroying the carcasses of all dead sheep by burning, the simplest, most feasible, and most effective means of eradication is to keep the dogs of the ranch or farm free from tapeworms by systematic medicinal treatment. As the sheep-measle tapeworm in dogs begins to produce eggs about two months after infection, judging from the results obtained in the experiments, it is evident that dogs should be treated about every two months in order to remove any tapeworms acquired since the preceding treatment before they have developed sufficiently to produce eggs. In practice, however, such frequent treatment seems scarcely necessary, and it is fairly certain that effective control of tapeworm infestation can be maintained if dogs are submitted to treatment four times a year—that is, every three months. The following method of treatment is employed by Dr. E. T. Davison at the Federal Quarantine Station at Athenia, N. J., and has proved very satisfactory in the case of imported sheep dogs quarantined and treated on account of tapeworm infestation:

Allow the dog to have the usual feed and drink about 3 or 4 p. m. on the day preceding treatment, but give nothing further in the form of food or drink, with

the exceptions noted, until after the medicine has acted. About 10 a. m., to a dog of ordinary size, give four 10-grain capsules filled with ethereal extract of male fern (Oleoresina aspidii, U. S. P.), administering at the same time about an ounce of water or milk, preferably the latter. By a 10-grain capsule is meant one which will hold 10 grains of quinine. Forty-five minutes later give a second dose, consisting of four capsules (10-grain) filled with freshly ground areca nut, and with this give as before about an ounce of water or milk. It is important that the areca nut be freshly ground. This treatment is usually followed by profuse defecation and the expulsion of the tapeworm, if any is present, in 30 minutes to an hour after giving the areca nut. No untoward aftereffects have been noted in any case among several hundred dogs treated with this remedy. The patient is usually ready for his evening meal.

In administering the medicine an assistant stands the dog up on his haunches and holds the dog's mouth open by firmly grasping the upper jaw in one hand, the lower jaw in the other. The capsules are dropped on the back portion of the tongue, and enough water or milk is thrown in the animal's mouth to make him swallow. After administering each of the two doses the dog's head should be tied up as high as he can hold it and not choke. If this detail is omitted, the patient will almost invariably throw up the dose. During the remainder of the day the dog should be kept in confinement and the fecal discharges gathered up and burned, buried, or otherwise disposed of in such a manner as to prevent the possibility of contaminating the feed or water of sheep or other live stock.

Incidentally it may be remarked that treating dogs for tapeworm will rid them not only of the sheep-measle tapeworm but also of other species of tapeworm whose intermediate stages are found in live stock, one of which, the gid parasite, fortunately as yet not widespread in the United States, affects the brain of sheep with almost invariably fatal results. Though in certain localities coyotes harboring tapeworms are undoubtedly responsible for some of the infestation of sheep with tapeworm cysts, yet it is the dogs accompanying the sheep more or less constantly day and night and depositing their feces laden with tapeworm eggs in the immediate neighborhood of the sheep which are the chief source of infestation, and if this source is removed by keeping the dogs free from worms, the sheep can be kept practically free from tapeworm cysts of all kinds. In addition, it is important that the carcasses of all dead sheep be destroyed by burning them in order to remove this source of infection of dogs and coyotes.

SUMMARY

Sheep measles, or tapeworm cysts in mutton, were first recorded in England in 1866 and the parasite named *Cysticercus ovis* in 1869 by Cobbold. *C. ovis* usually has been considered identical with *Cysticercus cellulosae*, the pork-measle parasite, and also has been confused with *C. tenuicollis*. It has been considered an intermediate stage of a human tapeworm, *Taenia tenella* or *T. solium*, and also of a dog tapeworm, *T. hydatigena* or *T. marginata*.

Cysticercus ovis is the intermediate stage of a dog tapeworm, *Taenia ovis* (Cobbold) Ransom. It may attain its full development in sheep in less than three months after infection, and in the dog the tapeworm may

reach the egg-producing maturity in seven weeks after the ingestion of the cysticercus.

Cysticercus ovis is commonly limited to the heart or diaphragm, but not infrequently occurs in the muscles of mastication and tongue and sometimes in various locations in the musculature. It may occur in the lungs, the wall of the esophagus, or the wall of the stomach. Doubtful locations are the kidney and liver. It is essentially a parasite of the intermuscular connective tissue and is evidently rare in other locations.

The cysticerci seen by meat inspectors are usually degenerated. Those located in the heart tend to degenerate early. Degeneration may be well established in less than three months after infection. Either partially grown or fully developed cysticerci may degenerate and may be associated with living cysticerci in the same carcass as a result of variations in longevity of the parasites or of repeated infections.

There is no known method of diagnosing the presence of *Cysticercus ovis* in the living animal. The parasites are to be recognised in the sheep carcass by their location in the musculature, by their small size, and by the lateral position of the head of the cysticercus, *C. tenuicollis* being found in relation with serous membranes, being of larger size when fully developed than *C. ovis*, and having its head in an apical position with reference to the caudal bladder. In some cases microscopic examination may be required to differentiate between these two species. The possibility exists of confusing degenerate cysticercus cysts with *Sarcocystis* cysts and with encysted foreign bodies, such as plant barbules.

Sheep measles have been reported from England, France, Germany, Algeria, German Southwest Africa, and New Zealand and have been found in sheep from seven Western States of this country. It probably occurs wherever sheep are attended by dogs, but has not yet been found in sheep known to have originated in the eastern United States (p. 45).

Over 17,000 of the sheep slaughtered under Federal supervision during the year 1912, prior to December 1, were found to be affected with measles. With the development of more efficient methods of inspection for *Cysticercus ovis* the number of cases detected will be relatively much more numerous. The number of infested sheep in the Western States probably exceeds, on the average, 2 per cent of the total number. Young sheep, not over 2 years of age, apparently are more likely to show infestation than old sheep.

Cysticercus ovis is of economic importance, first, because of the losses resulting from the condemnation of carcasses found by the meat inspector to be more or less heavily infested, and, second, because of the direct losses which probably occur among sheep as a result of the invasion of the parasites. The extent of these losses can not be estimated at present.

Cysticercus ovis is of special interest in meat inspection because it affects the musculature and because it is so prevalent. Carcasses which

are only slightly infested may properly be passed for food after the removal of the parasites, but carcasses showing a heavy infestation should be condemned. Moderately infested carcasses may be rendered into edible tallow, but are usually treated the same as condemned carcasses and are manufactured into fertilizer and other inedible products. As *C. ovis* is not transmissible to man, meat-inspection regulations concerning it need not be so stringent in certain respects as those governing beef measles or pork measles.

The length of time *Cysticercus ovis* may survive after the death of its host has not been determined.

The most important preventive measures against the infestation of sheep with *Cysticercus ovis* consist, first, in destroying by fire the carcasses of dead sheep on the farm or range so that they may not be devoured by dogs or wolves, and, second, in keeping dogs free from tapeworms by systematic medicinal treatment. These measures will also protect sheep from infestation with tapeworm cysts of various other kinds, which they acquire from dogs.

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1873 c. The internal parasites of our domesticated animals; a manual of the Entozoa of the ox, sheep, dog, horse, pig, and cat. London, ix+144 p., 28 fig. 12°. [Wa, Wm.]

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DESCRIPTION OF PLATES

PLATE II. Fig. 1.—*Cysticercus ovis* from lamb which had been fed eggs of *Taenia ovis* (lamb No. 1, p. 23).

Fig. 2.—*Cysticercus cellulosae*. The cysticerci have been extracted from their cysts. Natural size. (From photographs.)

Fig. 3.—*Taenia ovis*. This tapeworm was developed by feeding *Cysticercus ovis* to a dog (dog No. 6, p. 23). One-half natural size. (From a photograph.)

Fig. 4.—*Taenia hydatigena* (*T. marginata*) from an imported sheep dog.

Fig. 5.—*T. hydatigena* (*T. marginata*) from a dog (dog No. 2, p. 21) which had been fed *Cysticercus tenuicollis*. In figure 5, diagonally above and below, are shown two small specimens of *C. tenuicollis* developed in a lamb (lamb No. 7, p. 25) by feeding segments of *T. hydatigena*. One-half natural size except the two cysticerci, which are shown natural size. (From photographs.)

III (colored). Figs. *A* and *B*.—Portions of muscle of sheep showing *Cysticercus ovis* (undegenerated) in situ.

Fig. *A*.—Section of hind leg showing two "deep" cysticerci. Fig. *B*.—Hind leg showing three "superficial" cysticerci. (Two-thirds natural size. Original.)

Figs. *C* and *D*.—Heart and portion of diaphragm of sheep showing *Sarcocystis* nodules likely to be mistaken for degenerate cysticerci. (Two-thirds natural size. Original.)

Fig. *E*.—Sheep heart showing numerous small degenerate cysticerci (*Cysticercus ovis*.) (Two-thirds natural size. Original.)

IV. Fig. 1.—Carcass of sheep showing a degenerate cyst of *Cysticercus ovis* at the point indicated by the penknife. (From a photograph by Dr. T. White and Dr. A. English.)

Fig. 2.—Degenerate cysts of *Cysticercus ovis* in muscle of sheep; portion of carcass shown in Plate III, figs. *A* and *B*. About natural size. (From a photograph by Dr. T. White and Dr. A. English.)


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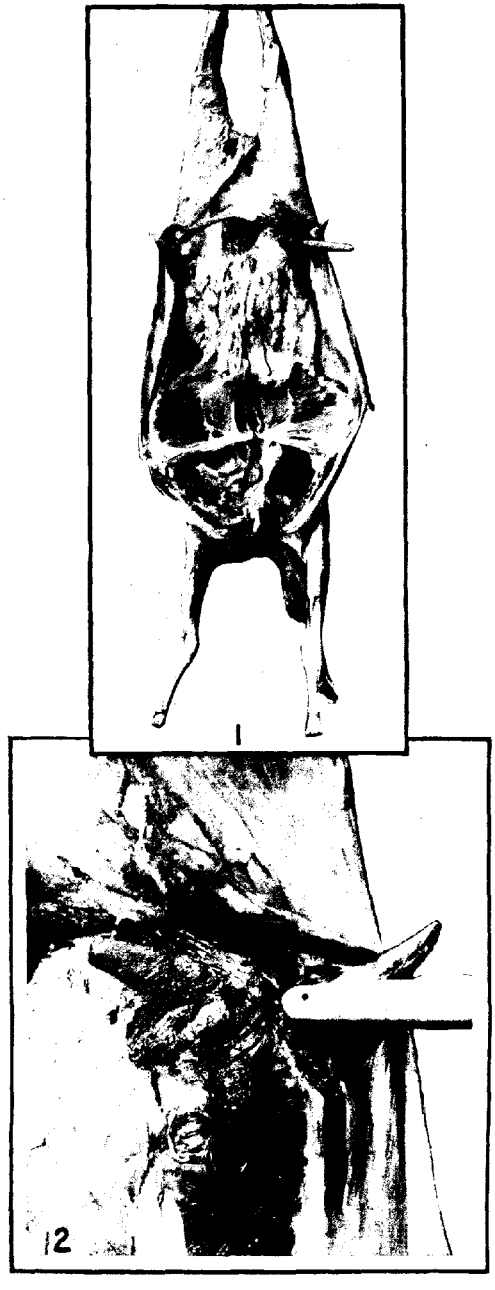
A
B
C
D
E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THE SERPENTINE LEAF-MINER

By F. M. WEBSTER, *In Charge*, and T. H. PARKS, *Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology*

INTRODUCTION

The serpentine leaf-miner (*Agromyza pusilla* Meig., fig. 1, *a*) was described in 1830 from central Europe[1] without definite locality or host plant. The family to which this insect belongs consists of a group of small flies the larvæ of which are largely leaf-miners. Some, however, are known to feed upon scale insects, while *Agromyza tiliae* Couden[2] and *A. magnicornis* Loew[3] are known to make galls on twigs of linden (*Tilia americana*) and on leaves of blue flag (*Iris versicolor*), respectively. Of the species of economic interest in America *Agromyza simplex* Loew occasionally becomes injurious to asparagus[4] by mining the stems. In Australia *A. phaseoli* Coq. seriously injures stems of growing beans,[5] while in India stems of young peas are similarly injured by a species of Agromyza.[6]

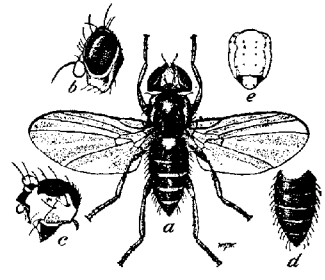

FIG. 1.—The serpentine leaf-miner (*Agromyza pusilla*): *a*, Adult; *b*, side view of head; *c*, side view of thorax, showing characteristic color pattern; *d*, dorsal view of abdomen, melanic phase; *e*, outline of thorax, showing location of characteristic bristles. Much enlarged. (Original.)

The habits of *Agromyza pusilla* as a leaf-miner of clovers have long been known, both in Europe and America, and its injuries have been recorded by some of the earliest students of entomology. With the rapid increase of alfalfa culture in the United States, especially in the irrigated sections of the West, the work of this leaf-miner as an enemy of forage crops has been more and more frequently called to the attention of the Bureau of Entomology. During the past three years this insect has been the

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[2] Couden, F. D. A gall-maker of the family Agromyzidæ. (*Agromyza tiliae*, n. sp.) Proc. Ent. Soc. Wash., v. 9, p. 34–36, fig. 1, 1907, 1908.

[3] Thompson, M. T. Three galls made by cyclorrhaphous flies. Psyche, v. 14, no. 4, p. 74, fig. 3, Aug., 1907.

[4] Chittenden, F. H. The asparagus miner. (*Agromyza simplex* Loew.) U. S. Dept. Agr., Bur. Ent. Circ. 135, 5 p., 2 fig., 1911.

[5] Froggatt, W. W. The French bean fly. (*Agromyza phaseoli*, Coquillett.) Agr. Gaz. N. S. Wales, v. 22, pt. 2, p. 151–154, Feb., 1911. Also pub. as N. S. Wales Dept. Agr. Misc. Pub. No. 1399.

[6] Maxwell-Lefroy, Harold. Indian Insect Life. Calcutta and Simla, 1909. p. 622–623.

subject of investigations and observations made by several members of the Section of Cereal and Forage Crop Insect Investigations, and the following results are herein set forth regarding this leaf-miner as an enemy of alfalfa (*Medicago sativa*) and other forage crops in America.

SYNONYMY

Mr. J. R. Malloch, recently of the Bureau of Entomology, after making a careful study of specimens from Europe and also of a large amount of material from widely separated localities in the United States, includes as synonyms of *Agromyza pusilla* the following names heretofore supposed to apply to valid species:

A. pusilla Meig., *A. pumila* Meig., *A. strigata* Meig., *A. exilis* Meig., *A. amoena* Meig., *A. puella* Meig., *A. pusio* Meig., *A. orbona* Meig., *A. blanda* Meig. (?), *A. diminuta* Walker (?), *Oscinis trifolii* Burg., *Oscinis brassicae* Riley.

HISTORY OF THE SPECIES IN EUROPE

According to Schiner, "the larvæ mine the leaves of *Euphorbia cyparissias*," the cypress spurge, also called "quacksalver's spurge," which according to Britton and Brown has escaped from gardens to the roadsides and waste places in the Atlantic States.

The same authority quotes Bouché as stating of *Agromyza amoena* Meig. that "the larvæ mine leaves of *Sambucus nigra*, the common European elder."

Kaltenbach records observing the larvæ of *Agromyza trifolii* mining in the leaves of *Trifolium medium* in June and in those of *T. repens* (white clover) in September. He also says of *A. strigata:* "The mining larva lives in leaves of *Campanula trachelium* (bellflower)."

Goureau,[1] in 1861, records *Agromyza nigripes*, a related European species, as mining in the leaves of *Medicago sativa* (lucern), in Europe, and his description of the habits and injury caused by these miners is very similar to that which might be given of *A. pusilla* and its injury to alfalfa in America.

Decaux,[2] in 1890, records *A. nigripes* as mining the leaves of lucern in France, and in the infested area estimates a loss of from 20 to 25 per cent of the crop due to the injury to the lucern leaves by this miner.

Groult,[3] in writing of *A. nigripes* in France, records the mines during August and September in fields of lucern and states that where large numbers of the mines were present the devastation became noticeable and the injured lucern made poor forage.

[1] Goureau, Charles. Les insectes nuisibles aux arbres fruitiers, aux plantes potagères, aux céréales et aux plantes fourragères. Bul. Soc. Sci. Hist. et Nat. de l'Yonne, v. 15, p. 76–454, juill., 1861. "*Agromyza nigripes*," p. 385–386.

[2] Decaux, François. [*Agromyza nigripes* Meig.] Ann. Soc. Ent. France, ser. 6, t. 10 [Bul.], p. ccvi–ccvii, nov. 26, 1890.

[3] Groult, Paul. *L'Agromyza nigripes*. Le Naturaliste [Paris], an. 30 (ser. 2, an. 22), no. 517, p. 219–220, sept. 15, 1908.

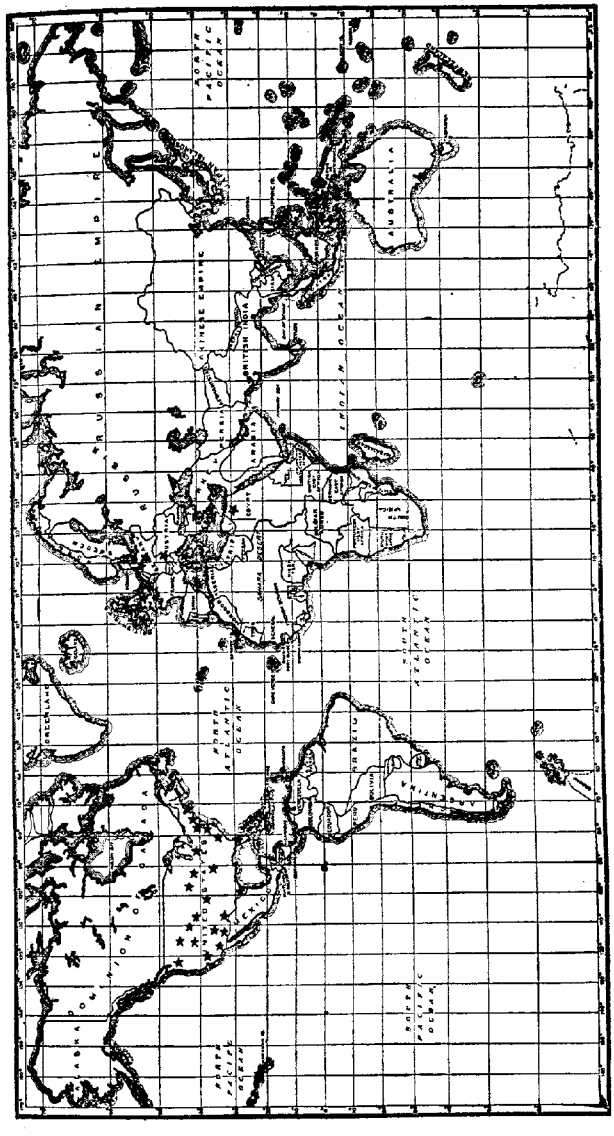

FIG. 2.—Map showing known distribution of the serpentine leaf-miner throughout the world.

Mr. H. S. Smith, formerly of the Bureau of Entomology, noticed dipterous larvæ mining leaves of lucern in fields in Sicily, Italy, and France during the spring of 1912, and from a pupa taken in one of these mines, collected in Sicily during the last week of December, 1911, reared *Agromyza nigripes*. He reports the work of this species in Europe as similar to that of the alfalfa leaf-miner in America with which he is familiar. Apparently the larva can be found mining in the lucern leaves in the latitude of Sicily during the entire winter.

DISTRIBUTION OUTSIDE OF THE UNITED STATES

Outside of the United States this species has been found in middle, central, and northern Europe—Italy, Sicily, Egypt, England, Scotland, and Ireland. Its general distribution is shown in the map of the world (fig. 2).

DISTRIBUTION WITHIN THE UNITED STATES

The general distribution of the species in the United States, excluding Alaska and the insular possessions, extends from the coast region of central New Jersey southward to southern Florida and westward to southern California and northwestern Washington. It also occurs about Honolulu, Hawaiian Islands. (See map of the United States, fig. 3.)

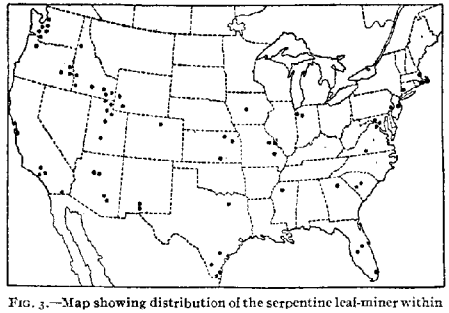

FIG. 3.—Map showing distribution of the serpentine leaf-miner within the United States.

Specimens are in the collection of the United States National Museum from the following localities:

Washington, D. C. (Coquillett and Pergande); Foristell, Mo. (Riley); Los Angeles, Cal. (Coquillett); Las Cruces, N. Mex.; Douglas County, Kans.; Flagstaff, Ariz.; Williams, Ariz. (H. S. Barber); Honolulu, H. I.; Iowa; Whittier, Cal. (P. H. Timberlake); Biscayne Bay, Fla.; Texas (Belfrage); Plano, Tex. (E. S. Tucker); Cotulla, Tex. (F. C. Pratt); Victoria, Tex. (Hunter).

Specimens in other collections are from the following localities:

Ocean County, N. J. (Dr. John B. Smith); Portland, Oreg. (Melander); Moscow Mt. (Melander); Mt. Constitution, Winlock, Port Gamble, Woodland, Palouse, Monroe, and Olga, Wash. (Melander); Pullman, Wash. (Melander and Hyslop); Philadelphia, Pa. (Henry Kraemer); Danbury, Conn.; Blue Hills, Woods Hole, Auburndale, and Chatham, Mass. (C. W. Johnson).

FOOD PLANTS IN EUROPE

According to Brischke, Brauer, and Kaltenbach the following host plants in Europe are given for *Agromyza pusilla* and its synonyms:

Agromyza pusilla Meig.:
- *Spiraea ulmaria* (meadow queen).
- *Solanum tuberosum* (potato).
- *Hyoscyamus niger* (henbane, hog bean).
- *Galeopsis tetrahit* (hemp nettle).
- *Stachys sylvantrica* (hedge nettle).
- *Euphorbia cyparissias* (cypress spurge).

Agromyza strigata Meig.:
- *Campanula trachelium* (bellflower).
- *Taraxacum geniculata* (dandelion).
- *Sonchus oleraceus* (sow thistle).

Agromyza strigata Meig.—Continued.
- *Bellis perennis* (garden daisy).

Agromyza trifolii Burg.:
- *Trifolium repens* (white clover).
- *Trifolium medium* (zigzag clover).

Agromyza orbona Meig.:
- *Ononis spinosa* (rest-harrow).
- *Ononis repens* (rest-harrow).

Agromyza variegata Meig.:
- *Colutea arborescens* (bladder senna).

Agromyza amoena Meig.:
- *Sambucus nigra* (European elder).

FOOD PLANTS IN AMERICA

Besides alfalfa, this species has been reared in the United States from the following plants, given here with the locality, date, and collector:

Cabbage (*Brassica oleracea*):
St. Louis, Mo., June 17, 1876 (C. V. Riley); Georgetown, D. C., July, 1882 (Theo. Pergande); Los Angeles, Cal., September, 1887 (D. W. Coquillett); Ames, Iowa, date unknown (Herbert Osborn), reared from stems; Washington, D. C., May and June, 1900 (Theo. Pergande); Athens, Ga., June 7, 1900 (Theo. Pergande); Brownsville, Tex., February, 1908 (D. K. McMillan); Orlando, Fla., March 24, 1908 (H. M. Russell); Honolulu, H. I., September, 1910 (H. O. Marsh), abundant and destructive; La Fayette, Ind., May, 1912 (W. J. Phillips and Philip Luginbill).

Nasturtium:
Washington, D. C., July, 1897 (D. W. Coquillett), Arlington, Va., June 30, 1906 (I. J. Condit).

Radish (*Raphanus sativus*):
Honolulu, H. I., July, 1906 (Jacob Kotinsky); Washington, D. C., July, 1907 (C. H. Popenoe).

Potato (*Solanum tuberosum*):
Foristell, Mo., June 3, 1876 (C. V. Riley).

Turnip (*Brassica rapa*):
Washington, D. C., July 30, 1906 (I. J. Condit); Corpus Christi, Tex., January 22, 1908 (D. K. McMillan); Arlington, Va., August, 1909 (E. G. Smyth).

Spinach (*Spinacia oleracea*):
San Francisco, Cal., 1907 (E. M. Ehrhorn).

Watermelon (*Citrullus vulgaris*):
Orlando, Fla., June 13, 1907 (H. M. Russell).

Garden beet (*Beta vulgaris*):
Honolulu, H. I., 1906 (Jacob Kotinsky).

Sugar beet (*Beta vulgaris*):
Compton, Cal., April 13, 1910 (H. M. Russell) (adults reared from pupæ collected on leaves); Elsinore, Utah, August 5, 1910 (E. G. Titus) (adults collected on sugar beets).

Pepper (*Capsicum* sp.):
Brownsville, Tex., February, 1909 (D. K. McMillan).

Vetch (*Vicia* sp.):
Columbia, S. C., June 15, 1913 (Philip Luginbill).
Sweet pea (*Lathyrus odoratus*):
Tempe, Ariz., May 24, 1912 (V. L. Wildermuth); Sacaton, Ariz., May 25, 1912 (R. N. Wilson); Salt Lake City, Utah, June, 1911 (C. N. Ainslie).
Fenugreek (*Trigonella foenum-graecum*):
Salt Lake City, Utah, July 22, 1911 (T. H. Parks).
White clover (*Trifolium repens*, Pl. V, fig. 2):
Washington, D. C., June, 1879 (Theo. Pergande); Oxford, Ind., 1884 (F. M. Webster); Washington, D. C., September 11, 1907 (C. N. Ainslie); Salt Lake City, Utah, 1911–12 (C. N. Ainslie and T. H. Parks); Lyman, Wyo., July 14, 1911 (T. H. Parks).
Red clover (*Trifolium pratense*):
Salt Lake City, Utah, June to September, 1911 (T. H. Parks); Twin Falls, Idaho, July, 1912 (T. H. Parks).
Sweet clover (*Melilotus officinalis*):
Tempe, Ariz., May 14, 1912 (V. L. Wildermuth).
Rape (*Brassica napus*, Pl. V, fig. 1):
La Fayette, Ind., 1909 (W. J. Phillips), La Fayette, Ind., 1911 and 1912 (W. J. Phillips and Philip Luginbill).
Cowpea (*Vigna unguiculata*):
Batesburg, S. C., July 12, 1904 (E. G. Titus); Lakeland, Fla., May 8, 1912 (G. G. Ainslie; La Fayette, Ind., July and August, 1912 (Philip Luginbill); Columbia, S. C., July 10, 1908 (G. G. Ainslie), September 11, 1912 (Philip Luginbill), Como, Miss., August, 1912 (T. H. Parks).
Cotton (*Gossypium barbadense*):
Batesburg, S. C., 1912 (E. A. McGregor); Dallas, Tex., 1912 (A. Rutherford).
Tobacco (*Nicotiana* sp.):
Chatham, Va., July, 1906 (W. W. Green).
Hedge mustard (*Sisymbrium officinale*):
Washington, D. C., June, 1900 (F. H. Chittenden and Theo. Pergande); Wellington, Kans., May, 1912 (E. O. G. Kelly).
Smooth rock cress (*Arabis laevigata*):
Washington, D. C., June, 1900 (F. H. Chittenden and Theo. Pergande).
Plantain (*Plantago* sp.):
Salt Lake City, Utah, July, 1912 (C. N. Ainslie).
Common mallow (*Malva rotundifolia*):
Tempe, Ariz., October, 1911 (V. L. Wildermuth).

The great variety in the food plants of the larvæ, together with the fact that the peculiar shaped but rather inconspicuous larval mines in the leaves (Pl. V, figs. 1 and 3) do not readily attract attention except when excessively abundant, leads to the suspicion that the insect may occur unobserved in many localities not indicated on the map (fig. 3). This is perhaps especially true throughout the West wherever it becomes sufficiently abundant in alfalfa fields to be a pest. Therefore, in this paper, it is considered with special reference to alfalfa culture.

RECORDS OF THE BUREAU OF ENTOMOLOGY

The earliest published record of this insect was by the late Dr. C. V. Riley, who appears to have first reared the fly from larval mines in the lower leaves of potato received from Foristell, Mo., June 3, 1876, other individuals issuing later. At that time it was supposed to be an Oscinis.

On June 17, 1876, Dr. Riley noted that cabbage leaves in the vicinity of St. Louis, Mo., were infested by some leaf-mining larvæ, and from these mines a single female fly was reared June 30, the larva pupating underground. Several years later, when apparently the same insect was found mining the leaves of cabbage, June 25, 1882, in Georgetown, D. C., by Mr. Theo. Pergande, interest in Dr. Riley's previous rearing from cabbage leaves in St. Louis, Mo., appears to have been revived. In 1884[1] Dr. Riley described the species as *Oscinis brassicae*, evidently failing to recognize as identical his former rearing from mines in potato leaves, but calling attention to the similarity between his species and *Oscinis trifolii* Burgess, which had been described five years before. This same year (1884) the senior author found the same species in large numbers attacking the leaves of white clover (*Trifolium repens*) at Oxford, Ind.

Three years after its first discovery in Missouri by Dr. Riley and during June, 1879, the insect was observed to be very abundant about Washington, D. C., attacking the leaves of white clover, and was carefully studied by Mr. Theo. Pergande. It must be borne in mind that at that time (1879) it was not positively known to attack clover or other plants elsewhere, and as a result of Mr. Pergande's labors adult flies were secured which were afterwards described by Mr. Edward Burgess as *Oscinis trifolii*.[2]

In 1898 the late Mr. D. W. Coquillett, after examining the types of both *Oscinis brassicae* Riley and *O. trifolii* Burgess, decided that both were synonyms of *Agromyza diminuta* Walk.[3] Further results are shown by Mr. Malloch's studies.

Its wide distribution in the alfalfa-growing section west of the Rocky Mountains was especially noted by the junior author during the summers of 1911 and 1912, when, during the months of June, July, and August, the larvæ were found mining in the leaves of alfalfa at almost every point visited in connection with the investigation of the alfalfa leaf-weevil (*Phytonomus posticus* Gyll.). The territory covered by these observations comprises most of the alfalfa-growing section of Utah, southern and western Idaho, and southwestern Wyoming. In fact, the mines were present in limited numbers wherever alfalfa was found growing and in places widely separated by the uncultivated desert. This may be illustrated by quoting from field notes made at Lucin, Utah, August 20, 1911:

> In a small field of alfalfa irrigated from a spring and in the midst of a desert west of Great Salt Lake these leaf-miners were of common occurrence. There is no alfalfa to the east for fully 90 miles and to the west for a distance of about 60 miles, this field being just 6 miles from the Utah-Nevada State line. Both larvæ and pupæ were observed.

[1] Riley, C. V. The cabbage Oscinis (*Oscinis brassicæ* n. sp.). U. S. Comr. Agr. Rpt. 1884, p. 322, pl. 8, fig. 5.

[2] Riley, C. V. The clover Oscinis. (*Oscinis trifolii* Burgess [n. sp.]). U. S. Comr. Agr. Rpt. 1879, p. 200–201, 1880.

[3] Coquillett, D. W. On the habits of the Oscinidæ and Agromyzidæ, reared at the United States Department of Agriculture. U. S. Dept. Agr., Bur. Ent., Bul., n. s., no. 10, p. 78, 1898.

Adults and pupæ were collected at Boise, Idaho, by Mr. H. T. Osborn, of the Bureau of Entomology, August 22, 1911; and from mined leaves of alfalfa received from Sarah A. Armstrong, July 3, 1905, from Fort Collins, Colo., adult flies of this species developed en route.

Its distribution extends westward to the Pacific coast, and throughout the irrigated sections of Washington, Oregon, and California. In a communication dated January 25, 1912, from Mr. Wyatt W. Jones, of Redding, Cal., the writer states that his attention has frequently been called to a minute leaf-miner in alfalfa, very common in that region during August and September. His attempts to rear adults resulted in securing only parasites. On May 14, 1912, Mr. Jones collected larvæ and pupæ from young alfalfa plants grown from seed sown in March of that year.

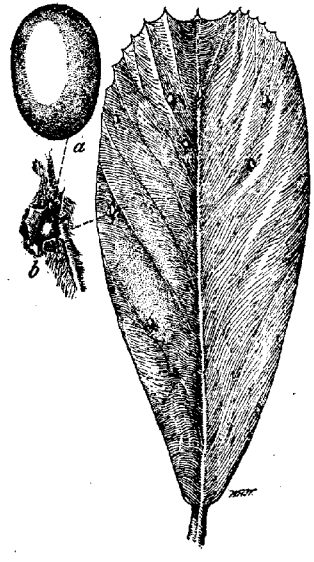

FIG. 4.—Alfalfa leaf with eggs of the serpentine leaf-miner in situ, somewhat enlarged. *a*, Egg, greatly enlarged; *b*, same, in situ, with parenchyma of leaf partly dissected away, much enlarged. (Original.)

Mr. V. L. Wildermuth, who has made a careful study of this insect in the Imperial Valley of southern California and in Arizona, finds it very generally distributed over the alfalfa-growing section of the Southwest, where its injury to the hay crop is probably greatest. It has also been swept from alfalfa at Glendale, Cal., by Mr. T. D. Urbahns.

These flies were reared from larvæ mining alfalfa leaves at Wellington, Kans., by the junior author in July, 1910, and again by Mr. E. O. G. Kelly, of the Bureau of Entomology, at the same place during the summer of 1912. While the injury was not severe, Mr. Kelly reported plants with from 12 to 20 mined leaves common during June.

Two adults and numerous parasites were reared from alfalfa leaves collected at Manhattan, Kans., by Mr. C. N. Ainslie in July, 1907. Mr. Ainslie also reared adults and parasites from infested leaves of alfalfa collected at Mesilla Park, N. Mex., May 21, 1909, and reported two or three mines in one leaflet not uncommon in the lower leaves of plants in a field of very young alfalfa.

Specimens have been collected from altitudes varying from below sea level in southern California to 7,000 feet above sea level elsewhere.

Throughout the entire West the mines were found in limited numbers wherever alfalfa is grown.

From the occurrence of the larvæ and pupæ in such widely scattered points we are led to believe that the insect has long been established throughout the alfalfa-growing sections of the West.

While this leaf-miner does not constitute a widespread menace to the alfalfa crop, it works considerable damage in New Mexico, Arizona, and southern California, because leaves mined by the larvæ are unfit for fodder; besides, the changed color of the hay reduces its market value, especially if grown mixed with timothy.

DESCRIPTION OF THE LEAF-MINER, AGROMYZA PUSILLA.

THE ADULT (FIG. 1)

In view of the great number of synonyms and the impossibility of giving descriptions of all of these in this article, Mr. Malloch has drawn up the following description, based on a large number of specimens in the collections of the Bureau of Entomology and the United States National Museum, the better to facilitate the recognition of the insect as it occurs in America.

MALE AND FEMALE.—Black, shining, marked in most variable degree with yellow. Frons, except ocellar region and sometimes a narrow side stripe posteriorly, yellow; remainder of head parts, except behind vertex, yellow. Mesonotum with a more or less broad yellow margin which never extends distinctly around the anterior or the posterior margin; four pairs of dorsocentral bristles present, as well as numerous short hairs on disk; humeri with a black spot. Pleuræ sometimes yellow, with a brownish spot above and shortly behind the coxæ, another large one covering the space between the fore and mid coxæ, and another one between the mid and hind coxæ; at other times almost entirely black, with the sutures and upper margin yellow. Scutellum entirely yellow, or yellow with black basal side spots, which in some cases extend almost around the entire margin and on to the disk. Postnotum black. Abdomen yellowish, with dark brownish bases to segments; or black, with pale apices to segments; or entirely shining black, with the apical segments whitish or yellowish at apex. Legs varying from almost entirely yellow, with only the tarsi brownish, to almost entirely black, with knee joints yellow; the femora generally less intensely black than other parts of legs. Mid tibiæ without distinct posterior bristles. Wings clear; second division of costa about two and one-half times as long as first section, third and fourth veins divergent at extremities; outer cross vein as long as or slightly shorter than the section of fourth anterior to it; basal two sections of fourth subequal or the second slightly the shorter; last section of fifth vein about three times as long as preceding section. Halteres yellow.

Length, 1 to 1.75 mm.

This is a most variable species in color and is very widely distributed.

THE EGG (FIG. 4)

The eggs are pale, white, oval, about 0.25 mm. long, and can be frequently seen through the epidermis from above. Figure 4, *b*, shows the egg partly dissected out of one of these pits.

THE LARVA (FIG. 5)

Larva, newly hatched, about 0.12 mm. in length, nearly white, but soon turning yellowish. When fully developed, it averages nearly 3 mm. in length, fully extended, and is bright translucent yellow, the black, chitinized mouth parts, tracheal system, and dark contents of the posterior alimentary canal being plainly visible through the body walls. Form subacute anteriorly, increasing rapidly in diameter caudad for about one-third of its length, then gradually diminishing posteriorly to the bases of the anal spiracles, where the body becomes rather suddenly truncate, terminating abruptly. Anal spiracles large, porrect, extending beyond end of cauda. Body segments visible and each encircled by a band, granular in appearance, which is sprinkled with minute setaceous tubercles. Anterior spiracles much smaller than posterior, somewhat chitinized at tips, knobbed, and situated in a slight depression.

FIG. 5.—Larva of the serpentine leaf-miner, lateral view. Enlarged. (Original.)

Upon the ventroanal surface there occurs a tubercular, suckerlike organ, in addition to which is a pair of rather large ventrolateral tubercles placed between the anal spiracles and the organ mentioned above. (Description by W. R. Walton.)

THE PUPARIUM (FIG. 6)

Puparium slightly less than 2 mm. in length, greatest width about 0.8 mm. Oblong oval in form, slightly flattened, the sides sinuate or fluted in outline. Segments strongly marked. Bright yellow in color when freshly pupated, gradually darkening to brown as the development of the pupa progresses. Surfaces slightly shining, but without sculpture. Anterior and posterior spiracles prominent, as shown in figure 6. (Description by W. R. Walton.)

FIG. 6.—Puparium of the serpentine leaf-miner, ventral view. Enlarged. (Original.)

HIBERNATION

Mr. George G. Ainslie finds that at Lakeland, Fla., the larvæ of the serpentine leaf-miner may continue feeding throughout the entire winter. They were observed by him mining in cowpeas in January, 1913. In the Salt River Valley of Arizona Mr. V. L. Wildermuth finds that during mild winters the larvæ may mine in the leaves until after Christmas. Ordinarily, however, in that locality, the larvæ go into hibernation late in November. At Brownsville, Tex., although we have no information relative to this species, Mr. R. A. Vickery finds that other insects do not hibernate at all, which agrees with what Mr. Ainslie observes to be true of this species in Florida.

It would seem, therefore, that the species hibernates north of Florida and extreme southern Texas and that, so far as known, hibernation takes place only as pupæ on or beneath the surface of the soil. In the North only a small percentage of the last generation in the fall lives to enter hibernation at all, owing to the fact that the larvæ continue feeding in their mines until late in the autumn, large numbers in this way being killed annually by the early freezes of October and November. In the Salt Lake Basin in Utah this insect begins to enter hibernation during

October, although many larvæ continue mining until killed by frosts. Moreover, a very large percentage of the larvæ in the mines are parasitized at this time, which greatly reduces the number of healthy pupæ that would otherwise enter hibernation. The junior author, in an effort to secure hibernating puparia at Salt Lake City in January, 1912, gathered old alfalfa leaves and loose soil from irrigation-ditch banks where the mines had been common during the summer of 1911, but only parasites issued from this material.

Healthy puparia formed late in October pass the winter in that stage in the latitude of northern Indiana.

Hibernation takes place largely in waste places where volunteer alfalfa is found growing. In the arid country of the West such patches of alfalfa can be found everywhere along irrigation-ditch banks, fence rows, and railway right of ways, where it escapes from cultivation.

BEGINNING OF ACTIVITY IN SPRING

Adults emerging from hibernation are abroad in April in southern California and Arizona and during the month of May in the intermountain region farther north. Evidently they do not travel far before oviposition takes place. As an indication of this it was noticed, both in Utah and again in Arizona and California, that the first mines observed in spring were usually either confined to the foliage of a single plant or scattered more or less sparingly over two or three adjoining plants. The occupants of these mines, whether larvæ or pupæ, were all in nearly the same stage of their development, thus indicating that the eggs were either deposited by a single female, or, if by more than one, at about the same date. It was noticed, also, that the female confines her oviposition to a small area, usually placing only one egg in a leaf. In the Salt Lake Basin the first mines in spring were usually found clustered on volunteer plants along irrigation-ditch banks, where the insect probably had hibernated.

OVIPOSITION AND THE EGG PERIOD

The eggs are deposited in the cellular tissue of the leaf, and the process of oviposition has been observed by several members of the Section of Cereal and Forage Insect Investigations of the Bureau of Entomology. The female deposits the egg from the underside of the leaf, frequently near the margin, where she can anchor herself by hooking the tarsal joints over the edge during oviposition. The fly inserts the ovipositor into the tissues, thrusting the tip of the abdomen against the leaf and puncturing the tissues with her ovipositor. She enlarges the opening thus made by a rotary motion of the abdomen and places the egg well up into the cellular tissue against the epidermis on the upper surface.

After the female has finished enlarging the opening she turns around and sucks up the sap from the aperture, after which she is soon engaged

in making another incision in the leaf, where she repeats the feeding operation. When several females are confined on one plant the underside of the leaves soon becomes pitted with these feeding punctures made with the ovipositor. Only a small percentage of the punctures contain eggs, as the main function of the punctures seems to be to furnish food for the adults. The larval mine always commences at this little hole or pit.

The females in confinement readily feed on sugar water, and, no doubt, nectar furnishes a part of their food, although no field observations prove this.

The egg period lasts from three to eight days, varying with the seasons of the year, but the average period of incubation can be considered as four days.

HABITS OF LARVA AND LENGTH OF LARVAL PERIOD

The larva (fig. 5) commences feeding immediately after hatching and starts mining through the tissues just beneath the upper surface. The mine at first is very small and threadlike, gradually widening with the growth of the larva. Often the miner encircles the entire leaf at first and then works into the uneaten center, and frequently the mine crosses like a figure 8. (See Pl. V, fig. 3.) If the leaf is small, the entire cellular tissue may be consumed, leaving only the epidermis; in such cases the larvæ have been observed to enter the leaf petioles and burrow a short way downward in an effort to secure enough food to bring them to maturity. The larva is not able to enter a fresh leaf in search of food, but perishes when the food supply in one leaf is insufficient to bring it to maturity.

FIG. 7.—Mouth armature of larva of the serpentine leaf-miner, greatly enlarged. (Original.)

The larva is provided with an oral appendage, or rasping organ (fig. 7), with which it breaks down the cellular tissue and conveys it to the mouth. This feeding "rake" is swung rapidly from side to side, twice a second or oftener, while the body moves in an arc as far as can be easily reached, when it is quickly brought back to the other end of the "swath" and the body moved up a minute distance to reach new cells. The larva continues thus feeding incessantly within its mine from the time of incubation until maturity. Mr. C. N. Ainslie observed that feeding took place at night as well as by day and that strong transmitted light thrown upon the larva had no effect upon it. It is indifferent to all external happenings, and the epidermis of the leaf may be stripped from the back of the feeding larva without disturbing it, provided the head is not uncovered. When the leaf epidermis is removed from the head, feeding ceases, and the larva can not be induced to resume it.

The larval period covers from 3 to 12 days; during the summer months it is passed in 4 or 5 days, the time increasing as the days get cooler. Many individuals are killed by the autumn frosts while they are yet partially grown. They will, however, continue feeding under remarkably low temperature conditions in an effort to survive; Mr. Wildermuth reared larvæ from the time of hatching till they were full grown in from 10 to 12 days under a mean daily temperature of 46.8° F., and where upon one occasion a minimum of 25° F. was reached.

PUPATION AND THE PUPAL PERIOD

The pupa (fig. 6), when found within the leaf, is always at the enlarged end of the mine where the larva stops feeding, and frequently in a cavity next to the lower surface, so that there is no indication that the puparium is present until the leaf is turned over to view it from beneath. The color is light yellow at first and gradually turns darker as transformation progresses, becoming a deep-brown color before the adult emerges. In the more humid section of the country the fully developed larva invariably forsakes its mine and descends into the ground from one-fourth to one-half inch below the surface, or crawls beneath some litter and there pupates. This is apparently true over the entire country with respect to the hibernating generation, but in the arid and semiarid regions of the West it has been observed that during spring and summer much of the transformation takes place within the larval mines in the leaves.

In the Salt Lake Basin and alfalfa-growing sections of southern Idaho and Wyoming pupation occurs almost entirely within the larval mines during the summer months. The junior author, who first studied the species at Wellington, Kans., and afterwards at Salt Lake City, Utah, at once noticed this difference in pupation habits in the two localities. This same thing was noticed at Salt Lake City, Utah, by Mr. C. N. Ainslie, who was rarely able to find mines from which the larvæ had emerged to pupate.

Mr. Wildermuth found that in the Imperial Valley of California during the month of April about 50 per cent of the larvæ pupate in the mines, but in the Salt River Valley of Arizona only a small percentage transforms within the mines, the majority forsaking the leaf and pupating in the soil. In Indiana, where this insect attacks cabbage, rape, and cowpeas, this transformation takes place entirely within the soil. This is also true in the region of the Southeastern States, where the mines are found in the leaves of cowpeas and, as observed by Mr. McGregor, to some extent in those of cotton.

No reason can be advanced to explain this difference in habit of pupation, a careful study of the humidity in these widely separated localities failing to offer any explanation therefor.

The pupal period during the summer months is about 10 days, but ranges from 8 to 28 days from April to December.

THE ADULT PERIOD

The fly (fig. 1, *a*) emerges through a slit cut in one end of the puparium and can be taken at almost all hours of the day in sweeping the foliage with a net. Adults put in confinement have lived 10 days after emerging, and the time elapsing between emergence and oviposition has varied from 4 to 10 days. The eggs are deposited soon after copulation and in the manner previously described.

LENGTH OF LIFE CYCLE

The following may be taken as the average period elapsing for the different stages of development during the months of June and July, at a latitude of 40°:

	Days.
Time elapsing between the emergence of the adult and oviposition	5
Egg period	4
Larval period	4
Pupal period	10
Average time for one generation	23

This period is considerably lengthened under existing low temperatures, and a maximum period of 35 or 40 days may be required in the cool weather of late autumn.

NUMBER OF GENERATIONS ANNUALLY

Since the larvæ continue developing late into the autumn and many of them are killed by the frosts of winter, the number of generations depends entirely upon the latitude, altitude, and length of the growing season. In northern Indiana during the season of 1912 Messrs. Phillips and Luginbill recorded six generations in a series of experiments carried on from the time the first larvæ were found in May until November.

From field observations and generation experiments conducted by the junior author and Mr. E. J. Vosler at Salt Lake City, Utah, there were found to be at least five generations from August 1, 1911, to August 1, 1912. The generation experiments in 1912 were started with adults swept from the fields in May, assumed to have issued from hibernating pupæ. The first generation in the spring is rather well defined and occupies about one month. As the season progresses, the generations so overlap that all stages of the insect can be found in the fields at the same time, and the life cycle was found to be shortened to a minimum of 18 days.

During the latter half of July and the month of August in the Salt Lake Basin it was noticed that the injured leaves of alfalfa in open fields were much more difficult to find than at any other time during the season. Moreover, alfalfa and white clover found growing in the shade were more generally infested than those growing in the open field. This was especially noted at Laketown, Utah, August 4, 1911, where a severe infesta-

tion was noticed on alfalfa plants growing in the bottom of a dry irrigation ditch where the vertical banks on each side kept the plants well shaded. At the same time very few mined leaves could be found in the open fields. There was, however, no interruption to the generation experiments carried on out of doors and in the shade at Salt Lake City, the adults continuing to emerge and larvæ to develop during this time.

Mr. Wildermuth, at Tempe, Ariz., during the season of 1912, remarked the almost total disappearance of all stages during the months of July and August, followed by their reappearance in September. He recorded three generations from the last of April to the last week in June and two more and a partial third generation between September and December of the same year. At Tempe adults did not emerge from the puparia in the generation experiments during July and August.

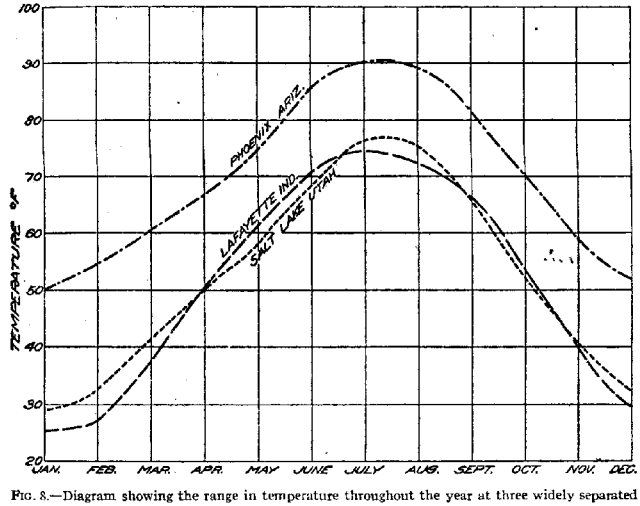

FIG. 8.—Diagram showing the range in temperature throughout the year at three widely separated localities at which observations were made on the serpentine leaf-miner.

In Arizona this disappearance of the insect apparently takes the form of a period of æstivation during the hot weather of midsummer, when the temperature in the open fields is too high for the successful propagation of the species. This is less noticeable in the cooler alfalfa-growing valleys farther north, where the summers are milder. Its presence in Utah alfalfa fields in much reduced numbers during August indicates that an attempt at æstivation is made there, but over a period of much shorter duration than is found farther south, in Arizona.

In this connection we here present (fig. 8) curves representing the normal mean temperatures recorded by the United States Weather Bureau at Salt Lake City, Utah, and Phoenix, Ariz. As will be seen by these curves the normal temperature at Phoenix, Ariz., from the first of

June until early September exceeds the highest mean temperature during the summer at Salt Lake City, Utah. This may in part explain the difference in habits of this insect at the two localities during midsummer.

INJURY TO FIELD CROPS OTHER THAN ALFALFA

MINING IN LEAVES OF COWPEA

This leaf-miner has been found burrowing in the leaves of the cowpea in widely separated localities by several agents of the Bureau of Entomology.

Dr. E. G. Titus, formerly an agent of the bureau, on July 12, 1904, found the leaves of the cowpea at Batesburg, S. C., generally attacked by leaf-mining larvæ, most of which had already escaped from the mines. He was able to rear two adults of this species and one hymenopterous parasite. Messrs. G. G. Ainslie and Philip Luginbill have observed mined leaves at Columbia, S. C., the former in July, 1908, and the latter in September, 1912. Mr. Luginbill also reared adults and parasites of this insect from their mines in cowpea leaves on the plats of the experiment station at Purdue University, La Fayette, Ind., in connection with studies made at that point extending from July 6 to August 7, 1911. These miners were attended by great numbers of parasitic Hymenoptera, *Euthrichopsis agromyzae* Vier.

The junior author observed larval mines in cowpeas at several points in Mississippi during August and September, 1912, but in every case the larvæ were parasitized or had escaped from the end of the mine through a slitlike opening and gone into the ground for transformation.

Mr. George G. Ainslie observed considerable injury to the cotyledons of young cowpeas at Lakeland, Fla., May 8, 1912, there being from 2 to 12 mines in each cotyledon—enough to make the leaves appear sickly and white. As many as 10 puparia were secured from moderately infested leaves. The larvæ left the mine to pupate.

The injury to cowpeas is seldom severe, because of the larger size of the leaf, but may become so when the larvæ are present in sufficient numbers in the cotyledon of very young plants before there is sufficient foliage to withstand their attack.

MINING IN LEAVES OF RAPE

The larvæ in large numbers were observed by Mr. W. J. Phillips to be mining in rape leaves at La Fayette, Ind., on July 6, 1909, and from the material collected adults of this species emerged July 9. Plate V, figure 1, shows one of these leaves containing several larval mines. The larvæ were observed to leave the mines and pupate on or beneath the surface of the soil, and the complete life cycle was found to be passed in from 25 to 28 days.

More extended studies were made of this species as infesting rape at La Fayette, Ind., during the season of 1912 by Messrs. Phillips and

Luginbill. Mines were also found in leaves of cabbage on May 9. They were first noticed in the leaves of rape on July 12, about the time the mines were noticed in this plant by Mr. Phillips three years before. A series of experiments was carried on from May until November with cabbage and rape as host plants, and a maximum of six generations was found to occur in that latitude.

Here again, as is the case wherever these mines are found, a very large percentage of the larvæ in them were found to be parasitized, and a large number of parasites were reared. Oviposition was observed, both in the field and in confinement, to take place precisely as in the leaves of alfalfa. The mines usually start from near the edge of the leaf, where the eggs are deposited, and extend part way around the leaf on the upper side, being visible only from above.

The extent of the damage to the crop under observation was not severe and, perhaps, could be reduced by destroying all the old plants at the end of the season and plowing deeply in the autumn to bury the hibernating pupæ.

Moreover, since cabbage seems to be a favorite food plant during the spring, it is readily seen that this crop should not be succeeded by or planted near rape, where trouble from this leaf-miner is anticipated.

MINING IN LEAVES OF COTTON

While primarily an enemy of forage crops, this miner has been found feeding in leaves of cotton in the Southern States. In 1906, adults were collected in cotton fields at Cotulla, Tex., by the late Mr. F. C. Pratt, and a year later taken in a cotton field by Mr. E. S. Tucker, of the Section of Southern Field-Crop Insect Investigations, Bureau of Entomology. During the summer of 1912, adults determined as this species were reared from cotton leaves at Batesburg, S. C., and Dallas, Tex., by Mr. E. A. McGregor, of the Section of Southern Field-Crop Insect Investigations, and by Mr. A. Rutherford.

The mines were observed at Batesburg by Mr. McGregor from the time of the first appearance of the cotton seedlings until July. Table I, prepared by him, shows the percentage of infestation which existed on July 12, 1912.

TABLE I.—*Infestation of cotton by the serpentine leaf-miner at Batesburg, S. C., July 12, 1912.*

Plants in row.	Plants infested.	Percentage of infestation.
81	69	85
107	84	79
156	136	87
[1]344	[1]289	[2]84

[1] Total. [2] Average.

Mr. McGregor's notes are as follows:

Data have not been accumulated from which to compute the percentage of leaves affected. It is quite evident, however, that at this season the plants outgrow the infestation and the rapidly forming leaves tend to reduce the percentage of infested leaves. This phenomenon easily leads to the erroneous inference that the pest prefers the seedling leaves and becomes less troublesome as the plants develop. On the contrary, later on in the season freshly formed leaves appear to be just as desirable to the leaf-miner as did the seedling leaves. The tortuous courses of the burrows often sever the main veins of the leaves, causing the death of more or less of the leaf, which may harbor several individuals.

The habits of the leaf-miner, as observed in cotton leaves by Mr. McGregor, are here quoted:

The duration of the larval stage, while not fully established, approximates a week. Feeding takes place and the tunnel is formed in the palisade tissue nearer the upper surface * * *, as the grub increases in size the caliber of the burrow expands until full development is attained at its cavernous end, when the larva escapes through a valvelike incision and pupates in the soil. In the laboratory adults issued six days after pupation.

Three hymenopterous parasites were reared by Mr. Rutherford from the pupæ of the host.

NATURAL ENEMIES OF THE SERPENTINE LEAF-MINER

Throughout its entire area of distribution this insect is severely parasitized. Excessive parasitism was noted in the earliest studies of the species about Washington, D. C., and the senior author reared numerous parasites from the larvæ mining in the leaves of white clover at Oxford, Ind., in 1884. In connection with the studies made during the last three years there have been reared at least 28 species of hymenopterous parasites from the mines of this insect in the foliage of alfalfa and other forage crops in the United States. At times these minute enemies have become so numerous as to render even a careful study of the pest itself a matter of some difficulty. But for their presence these leaf-miners would beyond a doubt work much more serious ravages in the alfalfa fields of the West than they do at present. Indeed, one is inclined to wonder what the actual financial effects would be were some condition to arise suddenly whereby the numbers and efficiency of these natural checks were radically diminished.

The first generation of the leaf-miner to appear in the spring is not severely parasitized, and from larvæ and puparia collected at this time numerous flies usually emerge. The following generation is more severely parasitized, and thereafter the parasites increase rapidly, infestation becoming more and more severe, so that mined alfalfa leaves collected during the summer and fall will usually yield parasites instead of adult leaf-miners. To illustrate this point, the junior author, near Salt Lake City, Utah, on September 16, 1911, selected in the field 45 mined alfalfa leaves, 43 of which contained 1 mine each, while 2 had 2 mines. Of the 47 mines,

3 contained healthy larvæ and 2 healthy pupæ of Agromyza, while the remaining 42 mines, or 89.7 per cent of those examined, contained parasites. Of these 42 mines, 25 contained parasitized larvæ, 14 parasitized pupæ, and 3 were doubtful. Of the 25 parasitized larvæ, 20 carried 1, and 5 carried 2 external parasites, making 30 parasites on the 25 larvæ of the leaf-miner; these, with the 14 parasitized pupæ, make a total of 44 individual parasites within the 45 mined leaves. In the Salt Lake Basin from June to October, 1911, 75 to 90 per cent of the mines in alfalfa leaves were found to be parasitized.

At Sacaton, Ariz., as early as May 25, 1912, Mr. R. N. Wilson, of the Bureau of Entomology, found 89 per cent of the insects issuing from mines of *Agromyza pusilla* to be parasites, while from material collected there in June and July parasites alone emerged.

Mr. Wildermuth, at Tempe, Ariz., from experiments conducted during the season of 1912, found that much the same degrees of parasitism existed in that locality; and while no record was kept to show the number of parasites found in occupied mines, Table II shows the number of adults and parasites which issued from large numbers of leaves containing Agromyza larvæ, collected in the field and kept in jars in the laboratory.

TABLE II.—*Emergence of Agromyza pusilla and its larval parasites in Arizona and California in 1912.*

Date leaves were collected.	Locality.	Experiment No.	Number of Agromyza issued.	Number of parasites issued.	Percentage of parasites to total insects issuing.
May 8	Tempe, Ariz.	1	2	80	97
May 10	do	4	4	33	89
May 14	do	6	5	41	89
May 23	do	8	0	68	100
May 31	do	9	3	31	91
June 10	do	10	0	40	100
Sept. 20	do	13	2	12	86
Oct. 1	do	14	3	22	88
Do	do	15	5	24	83
Oct. 14	do	16	3	12	80
Oct. 18	do	17	8	19	70
Oct. 19	do	18	1	12	92
Do	do	19	1	20	95
Do	do	20	9	16	64
Nov. 2	do	21	30	48	61
	Total		76	478	86.2
Apr. 18	El Centro, Cal.		6	18	75
Apr. 20	Brawley, Cal.		4	12	75
Apr. 22	Bard, Cal.		1	8	88

As will be noted in Table II, the high percentage of parasitism falls off rapidly upon the approach of cool weather, thus enabling the insect to enter hibernation with a much reduced degree of parasitism. At Lakeland, Fla., where no hibernation occurs, Mr. G. G. Ainslie records

no parasites present during January, 1913, among the larvæ feeding in cowpeas. From this fact it naturally follows that the season of greatest injury to forage crops from leaf-miners will be during a period of prolonged cool weather, when the temperature will naturally be unfavorable to the rapid multiplication of the parasites. This is precisely the condition that exists where there are destructive outbreaks of the green bug (*Toxoptera graminum* Rond.) as then the native parasites are unable to keep the pest in check. Of the life history of most of the parasites reared in connection with this leaf-miner comparatively little is known.

Diaulinus begini Ashm.—The parasite most thoroughly studied, as well as the most abundant, widely distributed, and hence most important in the control of the host is a small chalcidoid, *Diaulinus begini* Ashm. (fig. 9), the larva of which feeds externally upon the body of the Agromyza larva. This parasite has been reared from mines in leaves of alfalfa, clover, cowpeas, and rape in Indiana, Kansas, Arizona, New Mexico, California, Utah, Wyoming, and Idaho by different members of the Bureau of Entomology and from mines of *Agromyza parvicornis* in corn leaves at Salt Lake City, Utah.

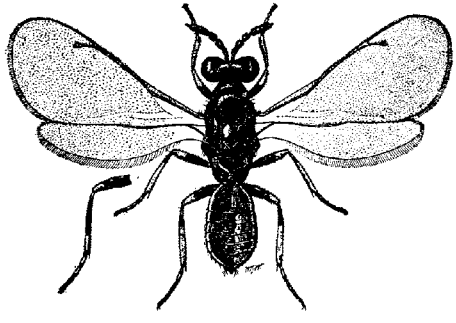

FIG. 9.—*Diaulinus begini*, a parasite of the serpentine leaf-miner. At left, hind leg of *Diaulinus websteri*. Greatly enlarged. (Original.)

The junior author was able to observe all stages of its development at Salt Lake City. The female parasite wanders about over the leaf until she locates the Agromyza larva in its mine below; then, pushing the ovipositor through the membranous tissue of the leaf which constitutes the roof of the mine, she places the egg upon the body of the host larva. The egg, as observed upon the surface of the host larva, is smooth, translucent, oblong, but rounded about equally at each end, and is about 0.5 mm. in length. The egg period is short, probably not lasting more than one or two days. The young larva feeds externally upon the body of its host, which dies while the parasitic larva is yet very young. Often the presence of the parasitic larva can not be detected on the body of the host without the aid of a microscope. The host larva is invariably dead whenever one of these larvæ, even though apparently just hatched, can be found on its body. Occasionally two larvæ feed on the body of a single host larva, and in one case both parasitic larvæ were observed to complete their transformations and emerge. The larval period is seven days. Figure 10 shows the full-grown larva. Pupation takes place

within the mines of the host and usually some distance away from the remains of its victim. Figure 11 represents the pupa of this species. The pupal period is seven or eight days, and thus the life cycle of the parasite is considerably less than that of the leaf-miner.

Diaulinus websteri Cwfd.* [1]—*Diaulinus websteri* (fig. 9, *a*) is very closely related to *D. begini* and, like the latter, it feeds externally upon the larva of its host. In the life-history studies made by the junior author at Salt Lake City, its habits were in no way distinguishable from those of *Diaulinus begini*, the two species being reared together from larvæ found attached to the same host. *Diaulinus websteri* has been reared from Agromyza from Kansas, Utah, Arizona, and California, being the most abundant parasite reared in southern California and Arizona. Of the two species of Diaulinus reared by Mr. Wildermuth at Tempe, Ariz., this species constituted 66 per cent of the material, while *D. begini* comprised 34 per cent. Of the Diaulinus reared at Salt Lake City *D. websteri* comprised only 18 per cent, while 82 per cent were *D. begini*.

FIG. 10.—Larva of *Diaulinus begini*. Greatly enlarged. (Original.)

This species was reared from mines of *Agromyza pusilla* in hedge mustard at Wellington, Kans., in 1912, by Mr. E. O. G. Kelly. Mr. C. N. Ainslie reared it from mines of *Cerodontha dorsalis* Loew in timothy leaves at Ely, Nev. It is also an enemy of *Agromyza parvicornis* Loew.

Chrysocharis ainsliei Cwfd.* and **C. parksi** Cwfd.*—These parasites (fig. 12) are very important in the control of *Agromyza pusilla* in the West. They feed internally and emerge from the puparia of the host. Their life history is imperfectly known. From hibernation material collected at Salt Lake City during the winter of 1911–12 adults emerged from April 18 to 20, which was 34 days before *Agromyza pusilla* was captured in the fields.

FIG. 11.—Pupa of *Diaulinus begini*. Greatly enlarged. (Original.)

From studies made by the junior author at Salt Lake City, Utah, in 1911 it was noticed that larvæ of Agromyza collected in the field, which pupated under observation in the laboratory, would often yield adults of Chrysocharis exclusively instead of those of Agromyza. Only one parasite issues from each puparium of the host, and dissections made of the puparia often revealed this to be entirely occupied by the larva or pupa of the single parasite, which had entirely consumed its host. But in some instances the puparium of Agromyza when dissected revealed two embryo parasitic larvæ within the body of the host larva. As only one adult is known to emerge from each puparium of the host, it is highly probable that when two internal parasitic larvæ

[1] The species of parasites marked with asterisks have been recently described in the Proceedings of the United States National Museum, v. 43, p. 163–188 (1912) by Mr. J. C. Crawford, Associate Curator, Division of Insects.

start to develop in one host, one kills and consumes the other. During September in the Salt Lake Basin 88 per cent of the puparia collected in the mined leaves of alfalfa yielded adults of Chrysocharis, and the two species were about equally represented. Both species have been collected in northern and central Utah, southern Idaho, the Imperial Valley of California, and in southern Arizona. *C. parksi* has also been reared from mined alfalfa leaves collected at Redding, Cal., in the Sacramento Valley. It was also reared from Agromyza mines in leaves of nasturtium and narrow-leaved plantain at Salt Lake City.

Derostenus arizonensis Cwfd.—This parasite of the larva of Agromyza constitutes a new species and is apparently confined to the Southwest. It was reared in large numbers by Mr. Wildermuth from mined alfalfa leaves collected in the Salt River Valley in Arizona, where it comprised 36 per cent of the larval parasites so reared. Three specimens were reared by Mr. Urbahns from mined alfalfa leaves collected at El Centro, Cal.

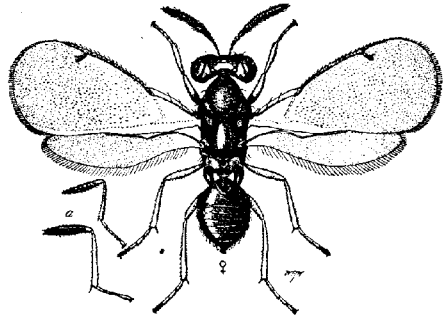

FIG. 12.—*Chrysocharis parksi*, a parasite of the serpentine leaf-miner. *a*, Middle and hind legs of *Chrysocharis ainsliei*. Greatly enlarged. (Original.)

A single specimen obtained from the large number of parasites reared at Salt Lake City, Utah, was reared from an Agromyza larva in a leaf of fenugreek (*Trigonella foenum-graecum*). It was described by Mr. J. C. Crawford in the Proceedings of the United States National Museum, volume 45, page 315, 1913.

Derostenus diastatae How.—This species has been reared from mines of *Agromyza pusilla* in cowpeas at La Fayette, Ind., by Mr. Philip Luginbill. In the Eastern States it is an important parasite of *Agromyza parvicornis* and *A. angulata*. It has not been recorded west of Kansas.

Derostenus punctiventris Cwfd.*—This insect was reared from puparia of Agromyza in mines in leaves of alfalfa at Salt Lake City, by Mr. C. N. Ainslie, and by the junior author, from alfalfa and white clover at Salt Lake City, Utah, and Lyman, Wyo. It was reared only occasionally and is of minor importance as an enemy of this leaf-miner. It also attacks *Agromyza parvicornis*.

Derostenus pictipes Cwfd.*—This parasite was reared from mines of *Agromyza pusilla* in cowpeas at Columbia, S. C., by Mr. G. G. Ainslie in 1908 and at La Favette, Ind., by Mr. Philip Luginbill in 1911. It was

also reared by Mr. C. N. Ainslie from mines of *A. coquilletti* Malloch in leaves of *Hordeum jubatum* collected at Fort Collins, Colo.

Derostenus varipes Cwfd.—A single specimen of this parasite was reared from *Agromyza pusilla* at La Fayette, Ind., by Mr. Luginbill. Nothing is known of its life history. It is a new species and was described by Mr. Crawford in the Proceedings of the United States National Museum, volume 45, page 315, 1913.

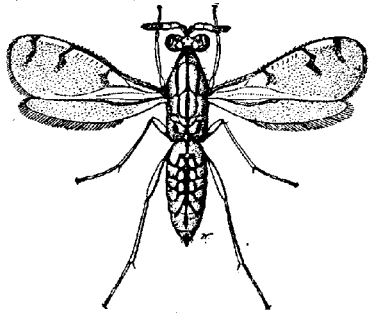

FIG. 13.—*Zagrammosoma multilineata*, a parasite of the serpentine leaf-miner. Greatly enlarged. (Original.)

Diaulinopsis callichroma Cwfd.*—This species was reared from mines in leaves of cowpea at La Fayette, Ind., by Mr. Luginbill and from alfalfa leaves at Tempe, Ariz., by Mr. Wildermuth. Very few specimens were secured, and it seems of little importance as a parasite of *Agromyza pusilla*.

Cirrospilus flavoviridis Cwfd.—Two specimens were reared from mines in alfalfa leaves at Salt Lake City, Utah, by Mr. C. N. Ainslie, who also reared it from mines of *Cerodontha dorsalis* Loew in timothy leaves at Ely, Nev. It is also recorded as a parasite of *Agromyza parvicornis*. It was described by Mr. Crawford in the Proceedings of the United States National Museum, volume 45, page 317, 1913.

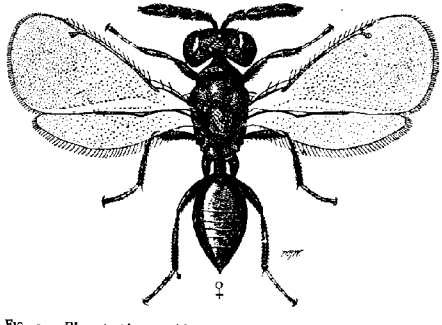

FIG. 14.—*Pleurotropis rugosithorax*, a parasite of the serpentine leaf-miner. Greatly enlarged. (Original.)

Zagrammosoma multilineata Ashm.—This species (fig. 13), described in 1888, has long been known as a parasite of a lepidopterous leaf-miner (*Lithocolletis* sp.), from which it was reared by the senior author in Ohio in 1893. Only three specimens were reared from *Agromyza pusilla*, two being reared at Wellington, Kans., by the junior author in 1910 and one by Mr. Luginbill at La Fayette, Ind.

Closterocerus utahensis Cwfd.*—A few specimens of this parasite were reared from mined alfalfa leaves at Salt Lake City, Utah, by Mr.

C. N. Ainslie and at Tempe, Ariz., by Mr. Wildermuth. Nothing is known of its life history. It is also recorded as a parasite of *Agromyza parvicornis*.

Pleurotropis rugosithorax Cwfd.*—This species (fig. 14) was reared sparingly from a puparium of *Agromyza pusilla* by both Mr. C. N. Ainslie and the junior author at Salt Lake City, Utah. It is an internal parasite, having been reared from the immature stages dissected from the puparia of the host. Only one parasite issues from each puparium of Agromyza.

Eucoila hunteri Cwfd.—This species was not previously known. Two specimens have been reared from puparia of *Agromyza pusilla* by Mr. A. Rutherford at Dallas, Tex. These issued 16 and 17 days, respectively, after the pupation of the host.

Sympiesis sp. (?)—One specimen of this species was reared by Mr. Kelly from mines in alfalfa leaves at Wellington, Kans., in 1912. It was also reared from mines in corn leaves at the same locality by the junior author in 1909. This is probably a new species and is not confined to one host.

MISCELLANEOUS UNDETERMINED PARASITES

The following miscellaneous Hymenoptera belonging to the superfamily Chalcidoidea [1] were reared from mines of *Agromyza pusilla*, the species being yet undetermined and their life history unknown.

Pteromalus sp.—(*a*) One specimen bearing Webster No. 6639 and reared from mines in alfalfa leaves at Salt Lake City, Utah.

(*b*) Three specimens bearing Webster No. 7492 and reared at the foregoing locality from mined leaves of white clover.

(*c*) Two specimens bearing Webster No. 7215 and reared at Tempe, Ariz., from mines in alfalfa leaves.

Cirrospilus sp.—One specimen reared from mines in alfalfa at Tempe, Ariz., and bearing Webster No. 7215.

Diaulinopsis sp.—Two specimens reared from mines in leaves of cowpea and bearing Webster No. 6395.

Entedoninæ.—One specimen from mined alfalfa leaves reared at Salt Lake City, Utah, and bearing Webster No. 6639.

BRACONID PARASITES

The following species of parasites belonging to the family Braconidæ were reared from *Agromyza pusilla* in accordance with the data given below.[2]

Opius agromyzae Vier.—La Fayette, Ind. (W. J. Phillips), Nos. 5170 and 6395.

Opius aridus Gahan.—Tempe, Ariz., May, 1912 (V. L. Wildermuth), No. 7215.

Opius brunneipes Gahan.—Lakeland, Fla. (G. G. Ainslie), No. 9489.

Opius suturalis Gahan.—Tempe, Ariz., May, 1912 (V. L. Wildermuth), No. 7215.

[1] Specimens determined to genus or subfamily by Mr. J. C. Crawford.

[2] The determinations are by Mr. A. B. Gahan.

PREDACEOUS ENEMIES OF THE SERPENTINE LEAF-MINER

Very few predaceous species are known to feed upon the serpentine leaf-miner. This is largely due to the fact that the larvæ feed well concealed within the leaf tissue and are thus not open prey. The following predatory insects are known to feed on some stage of the leaf-miner:

Triphleps sp.—These adults are recorded by Mr. E. G. Smyth, recently of the Bureau of Entomology, at Tempe, Ariz., to pierce with their beaks the Agromyza larvæ in their burrows.

Erythraeus sp.—These red mites are recorded by Mr. Wildermuth at Tempe, Ariz., to attack and kill the Agromyza larvæ in their tunnels. Mr. Nathan Banks determines this as probably a new species.

REMEDIAL AND PREVENTIVE MEASURES

The excessive parasitism under which this species exists has so far prevented it from becoming destructively abundant or doing any widespread serious injury. In case through any cause it should become more injurious to alfalfa, doubtless cutting the crop for hay at once as soon as the depredations were observed would prevent a recurrence. Its greater abundance along ditches, roadsides, and other neglected places indicates that frequent cutting of the alfalfa acts as a permanent check upon the increase of the insect. East of the arid regions deep fall plowing would bury the pupæ so deep in the ground as to put them beyond the possibility of emerging as adults. This is especially recommended for the annuals, such as cowpeas and rape. Throughout the remaining western country keeping down volunteer growth along ditch banks and in waste lands would greatly diminish the number of pupæ which yearly enter hibernation. Of course, pasturing either clover or alfalfa would destroy all larvæ mining in the leaves eaten off by the grazing.

OTHER SPECIES OF THE GENUS AGROMYZA LIKELY TO BE MISTAKEN FOR THE SERPENTINE LEAF-MINER

The species of Agromyza are for the most part very similar to one another in appearance. As a consequence there has been much confusion in their proper classification, and as a further result of this confusion articles have been published relating to one species which in the light of our present knowledge clearly belong to another. It is with the hope of preventing further errors of this nature that the following species of Agromyza—the first of which has in the last year or two been confused with the serpentine leaf-miner—are briefly treated in this paper:

Agromyza angulata Loew.—This leaf-miner (fig. 15) attacks leaves of timothy, mining between the membranes in the same manner as the serpentine leaf-miner.

It was reared from puparia (fig. 16) in leaves of timothy found July 4, 1895, near Bladensburg Road, D. C., by Mr. Theo. Pergande.

During July, 1912, Mr. Philip Luginbill at La Fayette, Ind., reared these adults from mines in leaves of volunteer timothy growing in protected places and was able to secure all stages of the insect.

The eggs are deposited in the cellular tissue just above the epidermis on the ventral side of the leaf, and in punctures similar to those made by *Agromyza pusilla* and *A. parvicornis*.

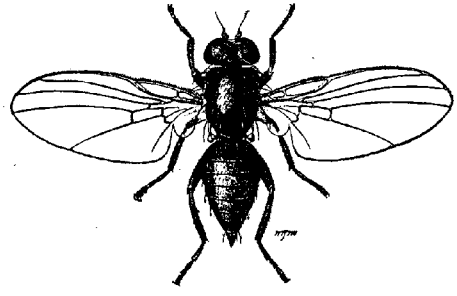

FIG. 15.—*Agromyza angulata*. Greatly enlarged. (Original.)

The egg stage is four to five days.

The larvæ feed in one leaf until mature and pupate in the mine. The larval period is 8 to 10 days, the pupal period, 13 days. This makes a total of 27 days elapsing from egg to adult.

Mr. Luginbill and Mr. Phillips were also able to transfer these miners from timothy to wheat, rearing one generation from wheat, using as parents flies reared from timothy mines.

The number of generations is not known. The following species of parasites were reared by Mr. Luginbill in connection with his studies in Indiana:

Polycystus foersteri Cwfd.; *Derostenus diastatae* How.; *Derostenus agromyzae* Cwfd.; *Pleurotropis rugosithorax* Cwfd.; *Entedon thomsoni* Cwfd.; *Notanisomorpha ainslici* Cwfd.

A single specimen was collected at Plummers Island, Md., July 28, 1912, by Mr. H. L. Viereck, and specimens collected at Niagara Falls, N. Y., and Auburndale, Mass., are present in the private collection of Mr. C. W. Johnson, curator of the Boston Society of Natural History. The species has never become sufficiently abundant to attract attention.

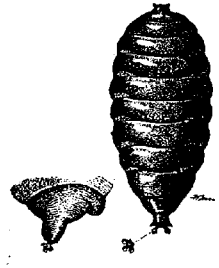

FIG. 16.—Puparium of *Agromyza angulata*, with lateral view of anal appendages at left. Greatly enlarged. (Original.)

Agromyza coquilletti Malloch.—This species (fig. 17) was reared from a puparium found among the basal leaves of volunteer wheat at Bucklin, Kans., November 6, 1909, by Mr. C. N. Ainslie. It was also reared at Fort Collins, Colo., by Mr. Ainslie from a larva mining a leaf of oats, June 30, 1910.

From three larvæ mining leaves of *Hordeum jubatum*[1] in the same locality on July 16, 1910, one adult of this species and seven hymenopterous parasites were reared. These were determined by Mr. J. C. Crawford as *Derostenus pictipes* Cwfd.

Larvæ were observed mining leaves of wheat at Roosevelt, Utah, June 25, 1912, by Mr. C. N. Ainslie, but from this material only parasites of the genus Pteromalus issued.

One specimen was reared from a blade of wheat at La Fayette, Ind., July 2, 1912, by Mr. Philip Luginbill, and the junior author reared one adult of this species from a larva mining a leaf of oats taken at Shoshone, Idaho, July 17, 1912.

[1] In this connection we note that Mr. Ainslie reared from various-shaped mines in Hordeum collected at Myton, Utah, June 27, 1912, two flies determined by Mr. Walton, of the Bureau of Entomology, as *Hydrellia scapularis* Loew. So far as can be ascertained, this is the first instance of the rearing of this species and the first report that it affects vegetation.

Three specimens have been swept from growing wheat at Manhattan, Kans., by Mr. C. N. Ainslie and one specimen from wheat at Lincoln, Nebr., by Mr. Geo. I. Reeves, of the Bureau of Entomology.

The following localities are represented in the collection of Mr. C. W. Johnson: Twin Rock, Pa. (Johnson); Nantucket, Mass. (J. A. Cushman); Norwich, Vt. (Johnson); Hanover, N. H. (Johnson).

The species has never become a serious enemy of wheat or oats.

Agromyza virens Loew.—This species was reared from larvæ taken in root stems of white clover at La Fayette, Ind., by the senior author in August, 1886. The maggots were found singly in the stem, sometimes just under the epidermis, and sometimes in the center. In either case parallel channels were excavated, the larvæ working from the point where the stem originated. These flies were determined tentatively as *Oscinis* sp., and a report[1] of the rearing describing the larva and pupa was published at that time.

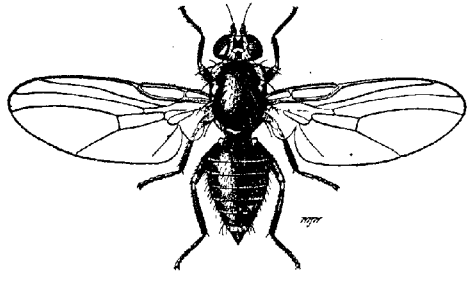

FIG. 17.—*Agromyza coquilletti*. Greatly enlarged. (Original.)

On October 19, 1898, these flies were reared from larvæ taken in the pith of the garden sunflower (*Helianthus annuus*) at Wooster, Ohio.

Mr. Theo. Pergande reared adults of this species from stems of *Mulgedium acuminatum* collected by the senior author at La Fayette, Ind., in November, 1885. Several undetermined hymenopterous parasites were reared from this material. These bear No. 3640. Mr. Pergande also reared one adult miner on April 18, 1883, from stems of a weed collected by Mr. Albert Koebele at Holderness, N. H., in October, 1882, and containing at that time mostly pupæ. He also reared an adult from a stem of *Ambrosia artemisiaefolia* (ragweed) received January 6, 1890, from A. M. Sharp at Gladbrook, Iowa.

It has also been reared from heads of *Rudbeckia* sp. at Dallas, Tex.

There are in the collection of the United States National Museum two specimens from Cambridge, Mass., marked "mining in stems of weed" (H. G. Hubbard); two "from stems of Ambrosia," March, 1895, District of Columbia; one "from *Nabalus albus*," May 14, 1883; two from California (Alameda and Los Angeles) collected by Mr. Coquillett; one from Flagstaff, Ariz. (H. S. Barber); thirteen from Toronto, Canada (William Brodie), one from Plummers Island, Md., and four from Washington, D. C., collected by Mr. W. L. McAtee.

Agromyza melampyga Loew, var. **marginalis** Malloch.—Three adults were reared from larvæ mining in leaves of grass (*Paspalum dilatatum*) by Mr. Philip Luginbill at Columbia, S. C., October 4, 1912.

SUMMARY

The serpentine leaf-miner is the larva of a minute yellow and black fly which is common in alfalfa fields during the summer.

It is generally distributed over the United States, having a wide range of food plants.

[1] Riley, C. V. The clover-stem maggot (*Oscinis* sp.). U. S. Comr. Agr. Rpt. 1886, p. 582, 1887.

The larvæ injure the foliage of the plant by burrowing between the membranes of the leaf and devouring the parenchyma.

The injury takes the form of a serpentine "mine" which encircles the leaf, gradually widening as the larva increases in size.

Leaves of white clover and frequently of young alfalfa often have the entire cellular tissue devoured, leaving only the two membranes.

There is usually only one larva present in each leaf.

The injury from this insect is greatest in the Southwest, where the discolored leaves, which in severe cases become brown, are sometimes present in sufficient numbers to lower the quality and grade of the hay.

The injured leaves can be found in the fields from May until November, the larvæ continuing to feed until killed by frosts. In Florida the larvæ continue feeding throughout the winter.

The insect hibernates in the puparia beneath the surface of the soil at the base of the plants.

There are five or six generations in latitude 41°, the number varying with the length of the growing season.

The generations overlap to such an extent that all stages can be found in the fields during most of the season.

During the period of highest temperature in summer the larvæ are found usually infesting plants protected from the direct rays of the sun. During this period in the arid Southwest the insect almost completely disappears from the fields, reappearing in September.

The eggs are deposited in the leaf tissue and inserted in punctures identical with those made by the adult in feeding. The egg stage during June is 4 days.

The larvæ feed continuously day and night and confine their work to a single leaf. The larval period during June is 4 days.

In the Eastern States pupation occurs entirely in the soil. It takes place commonly in the larval chambers in the leaf in the arid Western States. The pupal period during June is 10 days.

The average period of the complete life cycle is 23 days.

Besides alfalfa the following field crops are subject to attack: Clover, cowpeas, rape, and cotton.

A few nearly related and very similar leaf-miners are known to attack timothy, wheat, oats, and grasses. When these crops are affected, the mine usually extends the entire width of the leaf, and may kill the plant if it is very young.

Numerous parasitic insects attack and consume the larvæ and pupæ within their mines. These are highly efficient and serve to keep the insect in control.

The efficiency of the parasites decreases upon the approach of cool weather.

Many of these parasites are functional in the control of more than one species of leaf-miner, and are very widely distributed.

Frequent cutting of alfalfa kills the larvæ in the leaves and does much to protect this crop. This method should be followed where the injury becomes serious.

Deep fall or winter plowing is advocated for annual forage crops and cereals in order to bury deeply the hibernating puparia located near the surface of the ground.

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DESCRIPTION OF PLATE

PLATE V. Leaves of different species, showing the work of the serpentine leaf-miner (*Agromyza pusilla*). Fig. 1.—Mines in a leaf of rape. Fig. 2.—Mines in leaves of white clover. Fig. 3.—Mines in leaves of alfalfa. (All nearly natural size. Original.)

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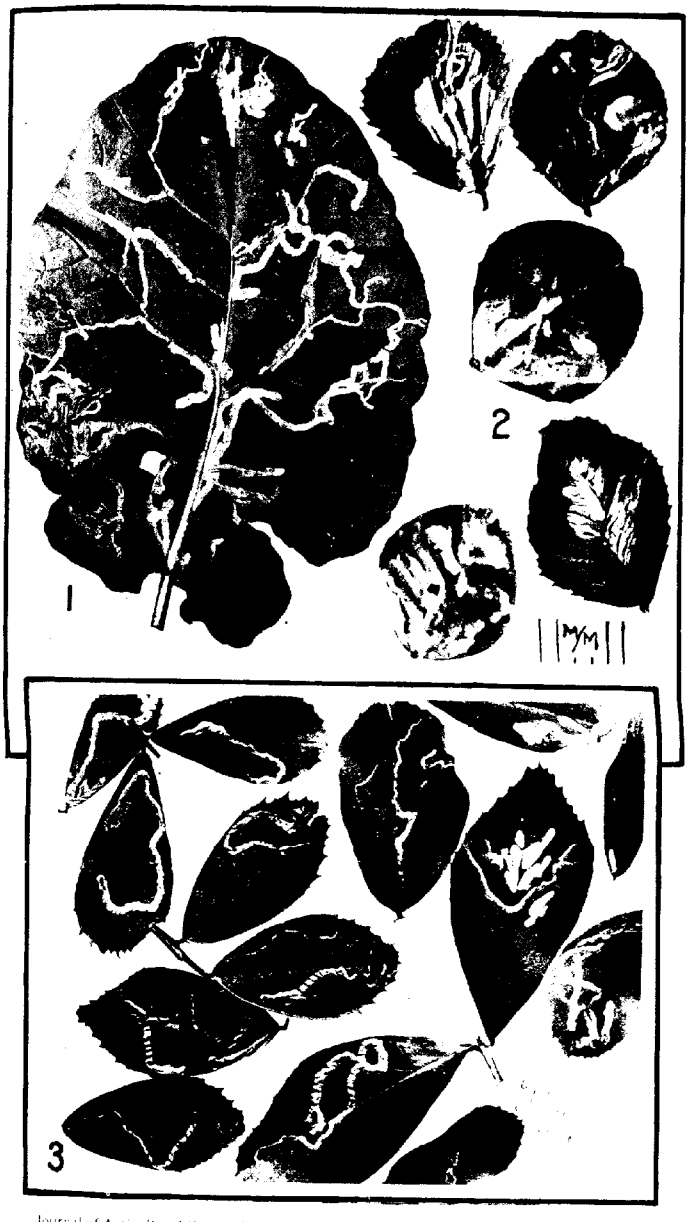
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